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EXHIBIT C
REDACTED

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UNITED STATES DISTRICT COURT
WESTERN DISTRICT OF PENNSYLVANIA

LAMBETH MAGNETIC STRUCTURES, LLC, Plaintiff, v. SEGATE TECHNOLOGY (US) HOLDINGS, INC. and SEAGATE TECHNOLOGY LLC, Defendants.	))))))))))))))	Civil Action No. 2:16-cv-00538-CB Judge Cathy Bissoon **CONTAINS CONFIDENTIAL ATTORNEY EYES ONLY INFORMATION SUBJECT TO PROTECTIVE ORDER**

PLAINTIFF LAMBETH MAGNETIC STRUCTURES, LLC'S
<u>INITIAL EXPERT REPORT OF DR. KEVIN COFFEY</u>

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I. INTRODUCTION

1. I, Kevin R. Coffey, Ph.D., resident at 2364 Foliage Oak Terrace, Oviedo, Florida 32766, have been retained by counsel for Plaintiff Lambeth Magnetic Structures, LLC ("LMS") to provide my opinion concerning U.S. Patent No. 7,128,988 ("'988 Patent"), including whether certain products manufactured, used, sold, offered for sale, and imported to the United States by Defendants Seagate Technology (US) Holdings, Inc. and Seagate Technology LLC (together, "Seagate") infringe claims of the '988 Patent, and whether certain products manufactured, used, sold, offered for sale, or imported to the United States by Seagate practice claims of the '988 Patent.

2. In reaching the conclusions described herein, I have considered the documents and materials identified in Appendix A, attached to this report. My opinions are further based upon my education, training, research and related publications, knowledge, and personal and professional experience in the relevant art.

3. I am prepared to testify to the matters set out in this report at trial. To support or summarize my opinions, any testimony I give may include appropriate visual aids, some or all of the data or other documents and information cited herein or identified in Appendix A, and additional data or other information identified in discovery.

4. I may modify or supplement my opinions and/or the basis for my opinions based on the nature and content of the documentation, data, proof, and other evidence or testimony that Seagate or its experts may present or based on any additional discovery or other information provided to me or found by me in this matter.

5. I am being compensated for my time at my standard consulting the rate of $250 per hour in conjunction with my work on this report. I am also being reimbursed for expenses

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that I incur. My compensation is not dependent on the results of my study, the substance of my testimony, or the outcome of this litigation.

6. In the last four years, I have provided expert deposition testimony in connection with the ITC investigation, In the Matter of Certain Acousto-Magnetic Electronic Article Surveillance Systems, Components Thereof, and Products Containing Same, Inv. No. 337-TA-904 on behalf of Tyco, Inc.

A. Professional Background and Qualifications

7. I am presently employed as a tenured Professor in the Department of Materials Science and Engineering at the University of Central Florida.

8. My general expertise is in the field of magnetic material structures and devices, including thin films and magnetic recording. I have made pioneering contributions to the following technical fields: magnetic materials, semiconductor interconnects, thin films, and magnetic recording.

9. I received a B.A. degree in Physics from New College in 1975 and a B.S. degree in Mechanical Engineering Technology from Florida International University in 1979. I worked as a physicist for Saxon Copystatics from 1979 to 1981 and for Nashua Corporation from 1981 to 1985. While working at Nashua Corporation, I attended graduate school at Northeastern University where I received a M.S. degree in Physics in 1985. My work at Nashua Corporation involved developing sputtered and plated thin film magnetic recording media.

10. From 1986 to 1989, I attended graduate school at the Massachusetts Institute of Technology and I graduated with a Ph.D. in Materials Science and Engineering in 1989. During that time, I worked as a research assistant and graduate fellow investigating Nb-Al reactions for superconducting wire applications.

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11. In 1989, I went to work at IBM where I performed research on thin film materials and processing directed towards magnetic recording head and disk applications. In 1995, I left IBM to work as the Manager of Magnetic Materials Research and Development at Sensormatic Electronics Corporation ("Sensormatic") where I led a team of engineers and scientists to develop semi-hard and soft magnetic materials, processes, and devices for electronic article surveillance applications. In 1997, I left Sensormatic to work as the Senior Director of Magneto-Optic Recording Media for Seagate Technology, where I led a group of engineering managers and scientists to develop novel magneto-optic recording media for optical applications. In 1998, I returned to IBM as a senior technical staff member. From 1998 to 2001, I managed a group of scientists and engineers developing new magnetic recording media process technology at IBM. From 2001 to 2002, I worked at IBM's Almaden Research Center pioneering new concepts in thermally assisted magnetic recording.

12. I am currently a tenured Professor in the Department of Materials Science and Engineering at the University of Central Florida, where I started working as an Associate Professor in 2002, after leaving IBM. My current research focuses on magnetic materials, semiconductor interconnects, and thin films. I also maintain an active graduate and undergraduate teaching program in electronic materials, materials kinetics, structure and properties of materials, and materials science of thin films. From 2012 to 2014, I was the Interim Chair of the Department of Materials Science and Engineering at the University of Central Florida. I have supervised 15 graduate students who received Ph.D. or M.S. degrees in materials science. Several of my students' research has been in the field of magnetic thin films.

13. I have published over 85 articles in the fields of magnetic materials, semiconductors, and thin films with a focus on solid state reactions in thin films and electronic

properties of thin films. I introduced the intermetallic $L1_0$ alloys (FePt, CoPt) as a candidate materials system for magnetic recording media, due to their high magneto-crystalline anisotropy, and have published 11 journal articles on this topic. I also introduced a new model for thin film reactions and made significant contributions to the study of electronic transport in metallic thin films. I am an inventor on 28 issued U.S. patents. I have given more than 60 conference presentations since 2002, including at the Annual Conference on Magnetism and Magnetic Materials, sponsored jointly by the Institute of Electrical and Electronic Engineers (IEEE) and the American Physical Society.

14. I am a Senior Member of IEEE and a member of the IEEE Electron Devices Society and the IEEE Magnetics Society. I am also a member of the American Physical Society ("APS"), the APS Topical Group on Magnetism and its Applications, and the Materials Research Society among other professional groups. I have reviewed articles for numerous peer-reviewed journals such as the Journal of Materials Science, the Journal of Electronic Materials, the Journal of Physics, and the Journal of Micromechanics and Microengineering. I have been on the program committee for several conferences and was co-chairman of the program committee for the 56th Conference on Magnetism and Magnetic Materials in 2011.

15. A copy of my curriculum vitae (CV), which contains information pertaining to my education, experience, scholarship, awards, and professional activities is attached as Appendix B and a list of publications and patents is attached as Appendix C.

B. Legal Standards

16. In this section I describe my understanding of certain legal standards. I have been informed of these standards by LMS's attorneys. I am not an attorney and I am relying only on instructions from LMS's attorneys for these legal standards.

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1. Infringement

17. I have been informed by counsel that a proper patent infringement analysis requires two steps. The first step is to properly construe the patent claims, which is a step taken by the Court. I understand that the Court issued a Memorandum Order construing certain claim terms in the '988 patent (Dkt. No. 78) ("Claim Construction Order") on October 18, 2017, and I discuss that Claim Construction Order in further detail below.

18. I am informed that the second step in an infringement analysis is determining whether a patent claim is infringed, considering the meaning of the claim terms as defined by the Court's construction. A patent claim is "literally" infringed only if each and every claim limitation is found in the accused product or method. I understand that LMS has the burden to prove infringement.

2. Infringement by the Doctrine of Equivalents

19. If not literally infringed, a patent claim might still be infringed under the "doctrine of equivalents." It is my understanding that if there are claim limitations that are not literally present in the accused product or method, the claim is still infringed if the difference between the accused product or method and the claims are insubstantial for each claim limitation. It is also my understanding that one test used to determine whether differences are insubstantial is to determine whether an accused element performs substantially the same function, in substantially the same way, to obtain substantially the same results of the claimed limitation.

20. I am also informed that an element in an accused product or method may be equivalent to a claim limitation if the two are known to be interchangeable at the time of infringement. I am further informed that the doctrine of equivalents does not apply when doing so would contradict statements made during the patent application process.

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21. It is my understanding that the range of equivalents is also limited by the prior art so that the scope of the patent claims does not cover the prior art, including what the prior art anticipates or what the prior art renders obvious.

22. Additionally, I understand that the doctrine of equivalents is subject to the "all elements" rule, which requires that an infringement theory based on the doctrine of equivalents may not read a limitation completely out of the claim.

3. Indirect Infringement—Induced Infringement

23. I understand that induced infringement requires a showing of direct infringement of the asserted claim by a single direct infringer, a person or entity that makes, uses, sells, offers to sell, or imports to the United States an infringing product. I also understand that induced infringement requires a showing that the party liable for induced infringement had knowledge of the patent and had knowledge that the induced acts of the direct infringer constitute patent infringement. I further understand that the knowledge requirement may be satisfied if the patent holder can establish that the direct infringer was willfully blind. Willful blindness requires that the indirect infringer have both a belief that there is a high probability that a fact exists, and taking deliberate actions to avoid learning of that fact.

4. Person of Ordinary Skill

24. I understand that central to the process of understanding the disclosures in a patent and assessing the validity of a patent is the notion of a person of ordinary skill in the art.

25. I understand that a person having ordinary skill in the art is a hypothetical person who is used to analyzing the prior art without the benefit of hindsight. A person of ordinary skill in the art is presumed to be one who thinks along the lines of conventional wisdom in the art and

is not one who undertakes to innovate, whether by extraordinary insights or by patient and often expensive systematic research.

26. I understand that factors such as the education level of those working in the field, the sophistication of the technology, the types of problems encountered in the art, prior art solutions to those problems, and the speed at which innovations are made, may help establish the level of skill in the art at the time of the patent in suit.

27. I understand that the hypothetical person of ordinary skill is presumed to have knowledge of all references that are sufficiently related to one another and to the pertinent art, and to have knowledge of all arts reasonably pertinent to the particular problem that the claimed invention addresses.

28. It is my opinion that a person of ordinary skill in the art would have either (1) an advanced degree in physics, electrical engineering, or materials science, and at least five years of relevant post-graduate experience in magnetic materials, structures, and/or devices; or (2) an undergraduate degree in physics, electrical engineering, or materials science, and at least ten years of relevant experience in magnetic materials, structures, and/or devices.

5. Non-infringing Alternatives

29. I understand that the availability or unavailability of non-infringing alternatives to the infringing products at the time of the hypothetical negotiation are relevant factors to consider when calculating damages based on a reasonable royalty. I also understand that if a non-infringing alternative was not on the market at the time of the hypothetical negotiation, in order for the non-infringing alternative to be considered available, relevant factors to consider are the feasibility, commercial acceptability, and cost of the non-infringing alternative. I further

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understand that if a non-infringing alternative was only theoretically possible at the time of the hypothetical negotiation, that is not sufficient for it to be considered available.

6. Damages Related Issues

30. I understand that, for the purposes of calculating damages as a royalty, the royalty base and royalty rate must appropriately reflect the value attributable to the infringing functionality of the accused devices. Therefore, a patentee should assess the revenue from the smallest saleable unit, and use that as a base for the royalty calculation. If the smallest saleable unit has multiple components, it may be appropriate to further apportion the percentage of revenue generated by the patented functionality.

31. I also understand that, as an exception to this analysis, if the patented feature or functionality drives demand for the entire accused product, then the entire market value rule applies, and the base of the damages calculation can be the sales of the accused product as a whole. I further understand that the entire market value rule is appropriate where both the patented and unpatented components together are analogous to components of a single assembly, parts of a complete machine, or constitute a functional unit.

32. I further understand that one of the methodologies for calculating damages is the hypothetical negotiation, in which the parties are assumed to negotiate a patent license, as a willing licensee and licensor, at the time that infringement began. Licenses and licensing terms in a comparable field of technology and relating to similar inventions can be instructive regarding the type of agreement that such a hypothetical negotiation would yield. I further understand that there are other aspects to determining whether a license is comparable beyond technological comparability, on which I am not offering any opinions in this matter.

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C. Technology Background

1. Crystal Structures

33. In crystalline materials, atoms or molecules have an organized geometry in repeating three-dimensional units called "unit cells." When the unit cell is repeated in all directions, it becomes a crystal lattice. The unit cell is the small volume, or building block, which contains the complete, repeating pattern of the crystal lattice. Examples of crystal structures found in metallic materials are face-centered cubic ("fcc"), body-centered cubic ("bcc"), and hexagonal close-packed ("hcp"). The unit cells of fcc, bcc, and hcp structures are shown below. The body-centered cubic structure contains one atom at the center of each cubic unit cell (*i.e.,* the center of the body of the unit cell) and atoms at each corner of the unit cell. The face-centered cubic structure also contains atoms at each corner of the unit cell and one atom in the center of each face of the cubic unit cell. The hcp structure contains a stacked hexagonal pattern of atoms. A bcc-derivative ("bcc-d") crystal structure is similar to a bcc crystal structure. *See also, e.g.,* Robert E. Reed-Hill & Reza Abbaschian, PHYSICAL METALLURGY PRINCIPLES at 5-10 (3rd ed. 1994) ("Reed-Hill"); R.E. Smallman & R.J. Bishop, MODERN PHYSICAL METALLURGY & MATERIALS ENGINEERING at 11-13; 18-21 (6th ed. 1999) ("Smallman"). An image of the arrangement of atoms in the face-centered cubic, body-centered cubic, and hexagonal close-packed structures are shown below, respectively.

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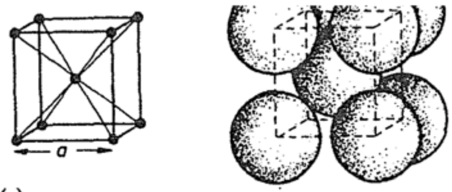

(c)

Figure 2.11 *Arrangement of atoms in (a) face-centred cubic structure, (b) close-packed hexagonal structure, and (c) body-centred cubic structure.*

is possible to define and express atomic arrangements in terms of structure cells (Section 2.2). Furthermore, because of the non-directional nature of the metallic bond, it is also possible to simulate these arrangements by simple 'hard-sphere' modelling.

There are two ways of packing spheres of equal size together so that they occupy the minimum volume. The structure cells of the resulting arrangements, face-centred cubic (fcc) and close-packed hexagonal (cph), are shown in Figures 2.11a and 2.11b. The other structure cell (Figure 2.11c) has a body-centred cubic (bcc) arrangement; although more 'open' and not based on close-packing, it is nevertheless adopted by many

The coordination number (CN), an important concept in crystal analysis, is defined as the number of nearest equidistant neighbouring atoms around any atom in the crystal structure. Thus, in the bcc structure shown in Figure 2.11c the atom at the centre of the cube in surrounded by eight equidistant atoms, i.e. CN = 8. It is perhaps not so readily seen from Figure 2.11a that the coordination number for the fcc structure is 12. Perhaps the easiest method of visualizing this is to place two fcc cells side by side, and then count the neighbours of the common face-centring atom. In the cph structure with ideal packing ($c/a = 1.633$) the coordination number is again 12, as

Smallman at 19, Fig. 2.11.

34. Miller indices are used to describe the crystallographic planes (a particular cross section of the unit cell) and directions in relation to the unit cells. For cubic unit cells, such as fcc and bcc, the directions are defined using the Miller indices [*uvw*] where *u*, *v*, and *w*, correspond to the Cartesian x, y, z coordinates of a vector in the direction of interest defined in a three-dimensional coordinate system oriented to the crystal as show in the figures below. Negative coordinates are represented by placing a bar above the index, *e.g.*, the opposite direction to [100] would be $[\bar{1}00]$. Miller indices can also be used to identify crystallographic planes using the form (*hkl*). The Miller indices of a plane indicate the inverses of the intercepts that the plane makes with the coordinate axes. The Miller indices of planes are enclosed in parentheses instead of square brackets to differentiate between planes and directions. For cubic crystals, the [*hkl*] direction is perpendicular to the (*hkl*) plane. The indices that describe planes and directions in hexagonal crystals can use four digits instead of three. These are called the Miller-Bravais indices wherein a plane is represented as (*hkil*) and a direction as [*hkil*]. Examples of several

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planes and directions in cubic unit cells and hexagonal crystal structures are shown below. *See also, e.g.*, Smallman at 13-16; Reed-Hill at 13-19. Note that, especially for cubic systems, some planes and directions are equivalent, differing only by the choice of the original coordinate system. Thus, the (100), (010), and (001) planes shown below all describe different, but equivalent sides of the cubic unit cell. A family of equivalent planes are described by different brackets, *i.e.,* {*hkl*} while families of equivalent directions are described by a fourth type of bracket, <*hkl*>. As an example, for a cubic crystal the [100], [010], [001], [100], [010], and [001] directions can be described as <100>. It should be noted that an incorrect usage of the notation for a single (*hkl*) plane or [*hlk*] direction while referring to a family of equivalent planes {*hkl*} or directions <*hkl*> is not uncommon. In these cases, the correct meaning needs to be inferred from the context of the usage.

> $(\bar{1}11)$, and $(11\bar{1})$, are represented as a group with the aid of braces enclosing one o the indices, that is, {111}. Thus, if one wishes to refer to a specific plane in a crysta of known orientation, parentheses are used, but if the class of planes is to be referrec to, braces are used.
>
> An important feature of the Miller indices of cubic crystals is that the integers of the indices of a plane and of the direction normal to the plane are identical Thus, face *a* of the cube in Fig. 1.16A has indices (100), and the *x* axis, perpendicula to this plane, has indices [100]. In the same manner, the octahedral plane of Fig 1.16C and its normal, the cube diagonal, have indices (111) and [111] respectively Noncubic crystals do not, in general, possess this equivalence between the indices of planes and normals to the planes. The spacing between crystallographic planes is covered later in Section 2.4.

Reed-Hill at 16, Fig. 1.16.

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the basal plane and is called the c axis, whereas the three a
basal plane are designated the a_1, a_2, and a_3 axes. Figure 1.18 sh
unit cell superimposed upon the four-axis coordinate system. I
take the unit of measurement along the a_1, a_2, and a_3 axes as th
atoms in a close-packed direction. The magnitude of this unit i
symbol a. The unit of measurement for the c axis is the height o
is designated as c.

Let us now determine the Miller indices of several impo
hexagonal lattice planes. The uppermost surface of the unit ce
responds to the basal plane of the crystal. Since it is parallel to t
a_3, it must intercept them at infinity. Its c axis intercept, howe
The reciprocals of these intercepts are $\frac{1}{\infty}$, $\frac{1}{\infty}$, $\frac{1}{\infty}$, $\frac{1}{1}$. The Miller i
plane are, therefore, (0001). The six vertical surfaces of the unit
prism planes of Type 1. Consider now the prism plane that form
the cell, which has intercepts as follows: a_1 at 1, a_2 at ∞, a_3 at –

Reed-Hill at 17, Fig. 1.18.

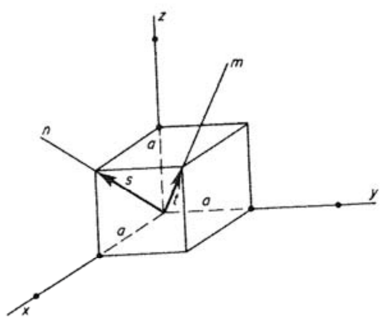

Fig. 1.13 The [111] and [101] directions in a cubic crystal; directions m and n, respectively.

Reed-Hill at 14, Fig. 1.13.

35. Both the (111) fcc plane of a crystal structure and the (0002) hcp plane of a crystal structure have a close-packed hexagonal arrangement of atoms, in which the atoms occupy a minimum area in the plane. The hcp materials will form a stacking sequence of ABAB of hexagonal close-packed planes which are designated as {0002} planes for hcp, while a stacking sequence of ABCABC for the close-packed planes leads to a fcc crystal structure where these close-packed planes are designated as {111} planes. However, both crystal structures are closely packed in three dimensions and have close-packed planes having a hexagonal arrangement of atoms. The figure below shows the stacking of close-packed planes.

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Magnesium	cph ($c/a = 1.623$)	0.320	Uranium	orthorhombic	0.275
Molybdenum	bcc	0.275	Vanadium	bcc	0.262
Nickel	fcc	0.249	Zinc	cph ($c/a = 1.856$)	0.266
Niobium	bcc	0.286	Zirconium	cph ($c/a = 1.592$)	0.318

plane must be in similar sites. (This is because neighbouring **B**- and **C** sites are too close together for both to be occupied in the same layer.) At this stage there is no difference between the cph and fcc structure; the difference arises only when the third layer is put in position. In building up the third layer, assuming that sites of type **B** have been used to construct the second layer, as shown in Figure 2.12b, either **A**-sites or **C**-sites may be selected. If **A**-sites are chosen, then the atoms in the third layer will be directly above those in

fcc or bcc. As indicated previously, an atom does not have precise dimensions; however, it is convenient to express atomic diameters as the closest distance of approach between atom centres. Table 2.1 lists structures that are stable at room temperature; at other temperatures, some metals undergo transition and the atoms rearrange to form a different crystal structure, each structure being stable over a definite interval of temperature. This phenomenon is known as allotropy. The best-known commercially-exploitable example is

Smallman at 20, Fig. 2.12.

36. Crystal orientation is measured by the alignment of a particular direction of the unit cell (defined by Miller or Miller-Bravais indices) with a reference direction. Often the orientations of the crystals in a material having many crystals (known as a polycrystal or polycrystalline material) are random and all crystal orientations are equally represented. However, the method of fabricating the polycrystalline material can result in materials with different preferred crystallographic orientations wherein one or more crystallographic directions are present more frequently than in a random distribution. The occurrences of such preferred crystallographic orientations are sometimes called "textures." Two crystalline orientations for bcc metals in sheet steel are shown below.

As one becomes more and more involved in the study of crystals, the need for symbols to describe the orientation in space of important crystallographic directions and planes becomes evident. Thus, while the directions of closest packing in the body-entered cubic lattice may be described as the diagonals that traverse the unit cell, and the corresponding directions in the face-centered cubic lattice as the diagonals that cross the faces of a cube, it is much easier to define these directions in terms of several simple integers. The Miller system of designating indices for crystallographic planes and directions is universally accepted for this purpose. In the discussion that follows, the Miller indices for cubic and hexagonal crystals will be considered. The indices for other crystal structures are not difficult to develop.

DIRECTION INDICES IN THE CUBIC LATTICE Let us take a cartesian coordinate system with axes parallel to the edge of the unit cell of a cubic crystal. (See Fig. 1.13.) In this coordinate system, the unit of measurement along all three axes is the length of the edge of a unit cell, designated by the symbol *a* in the figure. The

Reed-Hill at 13, Fig. 1.12.

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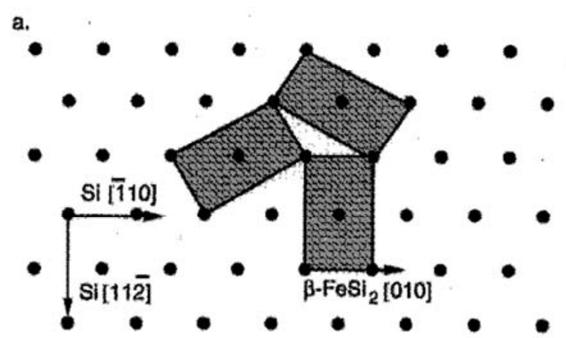
2. Thin Films and Epitaxial Growth

37. Epitaxial growth refers to extended single-crystal film formation on top of a crystalline substrate. Milton Ohring, Materials Science of Thin Films at 417 (2nd ed. 2001) ("Ohring"). In some cases, the crystalline films form in oriented domains that are rotated relative to one another. An example of such an orientation relationship is shown in the below figure of a ß-$FeSi_2$ crystalline film epitaxially grown on a silicon (Si) substrate with the (101) plane of the ß-$FeSi_2$ on the (111) plane of Si, which is a fcc material. *See also, e.g.*, Ohring at 424-425.



Ohring at 425, Fig. 8-4(a).

38. The ß-$FeSi_2$ rectangles shown above have a long side that is 1.732 times greater than the short side, as that is inherent in the geometry of a hexagon, and hence the only possibility for the hexagonal template plane. The □-$FeSi_2$ does not have a cubic crystal structure; it has a rectangular face on its (101) plane that can match up to the hexagonal pattern of the Si (111) along both the long and short sides of the rectangle. *See* Ohring at 424-425.

39. For the (110) plane of a cubic crystal, this type of epitaxy (matching in two directions) on a hexagonal template is not possible. The (110) plane of a cubic crystal will have a rectangular pattern, but with the long side only 1.414 times longer than the short side.

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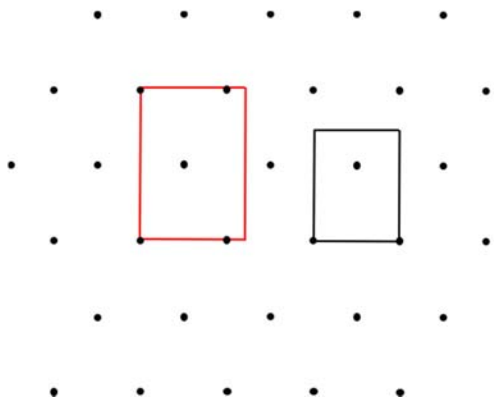
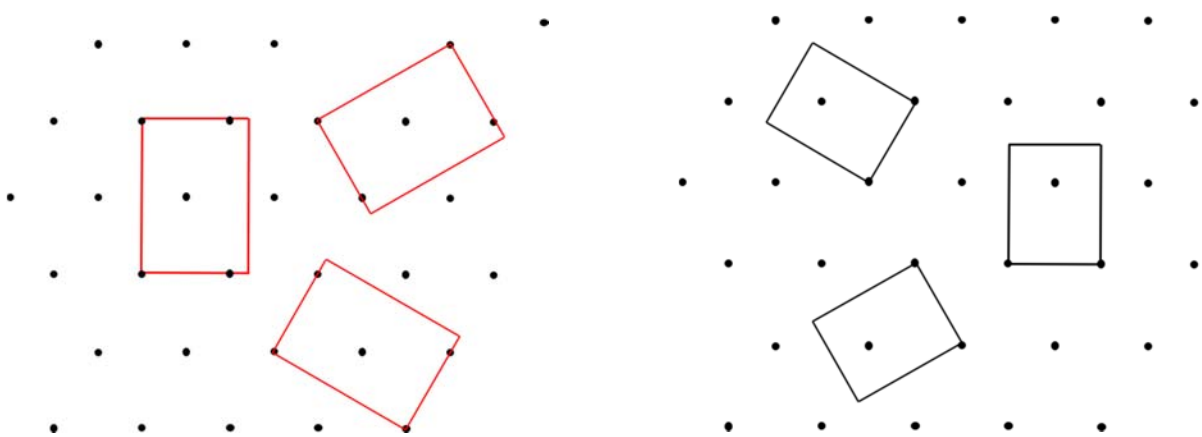
Therefore, the long side might match, or the short side might match, but to match both would require an extreme distortion of the bcc crystal. Two examples of this type of epitaxy are shown below, one with a larger cubic crystal, such that the long side can match with the hexagonal template, and one with a smaller cubic crystal such that the short side can match with the hexagonal template. As can be seen in the figure below, matching in one but not both directions of the (110) plane is possible for a cubic crystal on a hexagonal template



40. This type of epitaxy is called a “one dimensional” epitaxy, as only a single direction in the plane can be matched. This is a three variant form of epitaxy, as for each of these two types of matching there are three different orientations for the one-dimensional matching a (110) cubic crystal plane with the hexagonal template, as illustrated in the two figures below.



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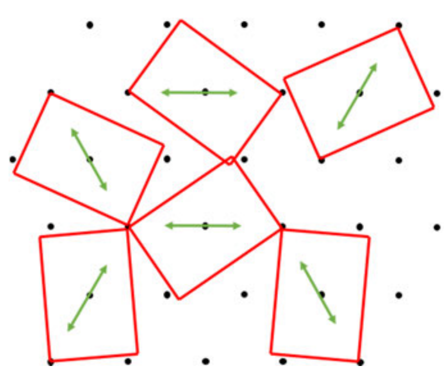
41. This type of epitaxy occurs for bcc(110) oriented crystals on fcc(111) and hcp(0002) hexagonal templates for sufficiently large or small bcc cubic crystals (compared to the hexagonal template). When the template for the bcc(110) oriented crystal is a fcc(111) crystal, both of these forms of epitaxy are known as the Nishiyama-Wasserman epitaxial orientation and are energetically favored when the ratio of the nearest neighbor distance (distance of closest packing between the crystal atoms) of the fcc crystal to that of the bcc crystal are either nearly equal to 0.9428 or nearly equal to 1.1547. For intermediate values of this ratio, near 1.0889, a different epitaxial orientation is energetically favored. This intermediate epitaxial orientation is known as the Kurdjumov-Sachs orientation. *See* van der Merwe and Braun, *Epitaxy at {111}fcc/{110}bcc metal interfaces*, APPLICATIONS OF SURFACE SCIENCE, **22/23** 545 (1985); Bauer and van der Merwe, *Structure and growth of crystalline superlattices: From monolayer to superlattice*, PHYS. REV. B, **33** 3657 (1986). A (111) plane of a fcc crystal serving as the hexagonal template and overlying (110) planes of bcc crystals oriented in the Kurdjumov-Sachs orientations are shown below. This orientation relationship does not require matching along the edge of the rectangle, rather the lattice matching occurs along the diagonal of the rectangle formed by the bcc(110) plane, as indicated by the green arrows. This is also a form of one dimensional epitaxy.



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42. This epitaxial orientation relationship is the six variant system described in the '988 patent. For the case of a (0002) plane of a hcp crystal serving as the hexagonal template, this six variant epitaxial system is known as the Burger's orientation, and is equivalent to the Kurdjumov-Sachs orientational relationship in the context of the '988 patent. Zheng, et al., *Determination of the structure of α-β interfaces in metastable β-Ti alloys*, ACTA MAT. **150** 25 (2018). Since it is evident from the '988 patent that the application of a magnetic field during deposition or annealing has an effect on choosing variants among the Kurdjumov-Sachs ("KS") variants (*see, e.g.*, '988 patent at 22:19-34), I expect such an application of a magnetic field will promote the Kurdjumov-Sachs variant system over the Nishiyama-Wasserman ("NW") variant system because the KS system permits better matching of easy axis orientations.

43. Epitaxial growth occurs through the deposition of atoms that form a crystalline film layer on a crystalline substrate. The deposition can occur through several possible methods, such as chemical vapor deposition and physical vapor deposition, in which the atoms forming the crystalline film layer are deposited from a vapor onto the crystalline substrate. Deposition can also occur through a liquid phase, as in electroplating, in which the atoms forming the crystalline film layer are deposited from a liquid solution onto the crystalline substrate. The atoms forming the crystalline film layer may settle into their lowest energy positions, which can result in epitaxial growth of the crystalline film layer if certain conditions, such as deposition speed and temperature, are carefully controlled. *See* Donald L. Smith, THIN-FILM DEPOSITION PRINCIPLES AND PRACTICE at 119-121, 221-226 (1995).

44. Epitaxial growth can occur where there is a crystalline substrate or a polycrystalline substrate. In the case of a polycrystalline substrate, each crystalline grain in the

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substrate provides a surface on which the deposited atoms may settle into their lowest energy positions relative to that grain. Accordingly, the texture and grains in a polycrystalline substrate can direct the growth of the layer deposited on it by epitaxial growth. A well-known example of polycrystalline epitaxy in magnetic recording is in regard to the epitaxial growth of hcp cobalt alloys on bcc chromium alloys for longitudinal recording media. *See* Freund, L.B. and S. Suresh, THIN FILM MATERIALS – STRESS, DEFECT FORMATION, AND SURFACE EVOLUTION at 45-47 (2003); Robert C. O'Handley, MODERN MAGNETIC MATERIALS at 696-699 (2000) ("O'Handley").

45. A characterization technique known as x-ray diffraction is commonly used to study the structure of crystalline materials. An example of x-ray diffraction scan data for a sample of polycrystalline Fe powder having a fully random orientation of its crystallites in three dimensions is shown below.

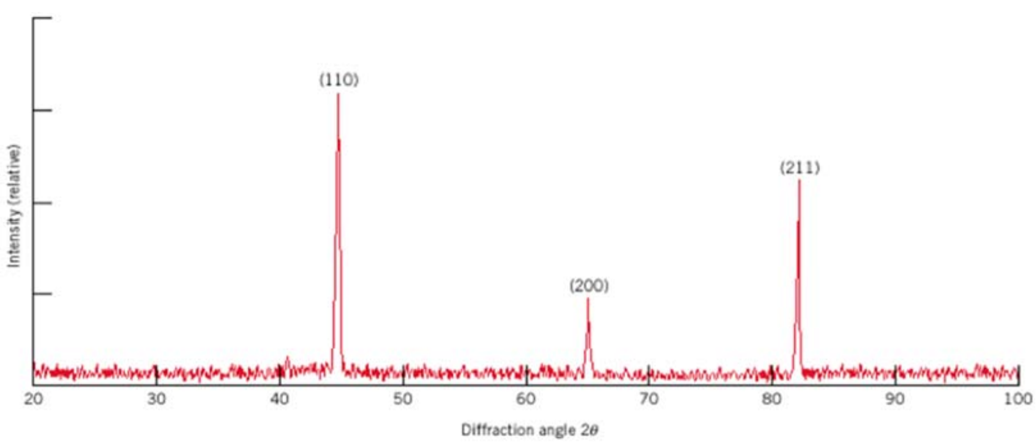

FIGURE 3.20 Diffraction pattern for polycrystalline α-iron.

Figure 3.20 from *Materials Science and Engineering: An introduction, 8th Edition*, by W.D. Callister, Jr. and D. G. Rethwisch, John Wiley & Sons, 2010 ("Callister")

46. As the diffraction angle is scanned, peaks in intensity can occur when Bragg's Law, □ = *2d sin(□),* is satisfied. In this equation □ is the wavelength of the x-rays used, *d* is the

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spacing between the (*hlk*) planes diffracting, and □ is the angle of incidence of the x-rays upon the diffracting plane. The diffraction intensity is commonly plotted as a function of 2□ , which is the total difference in angle between the incident and diffracted x-rays. The intensity of the peaks is dependent upon crystals being present having planes at the Bragg angle □ to the x-ray beam. By noting which peaks are present, the crystal structure may be identified. From the measurement of peak positions and the known value of the x-ray wavelength, the spacing between planes, d, can be accurately determined from Bragg's Law. This spacing is related to the lattice constant for cubic crystals by the crystal geometry, wherein the lattice constant (length of the cube edges) is given by $d\sqrt{h^2 + k^2 + l^2}$. *See, e.g.*, Callister at Chapter 3.

3. Magnetic Materials

47. A bar magnet with a north and south pole, as shown below, is made of a "hard" magnetic material, meaning that once magnetized it stays magnetized, a "permanent" magnet. For a typical bar magnet, the pair of opposite directions along the length of the magnet is the "easy axis," while the two sets of opposite directions along both the height and width of the magnet are the "hard axes." This means that it is more difficult to magnetize the material when the field is applied along either the height or width of the bar, and easiest to magnetize the material when the field is applied along the length of the bar.

48. Anisotropy means that a particular property of a material is a function of direction. In magnetic materials, the preference for the magnetization to lie in a particular direction is referred to as magnetic anisotropy. The magnetization direction of an object made of

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magnetic material can be influenced by its shape, mechanical strain, and an applied external field as well as by the intrinsic properties of a material. The shape, strain, and external field are not considered material properties as they reflect the object that the magnetic material is made of and external forces acting upon the object. For example, if the conventional bar magnet shown above were made into an assembly of bar magnets stacked directly on top of each other, then the easy axis of magnetization of the assembly would change to the stacking direction, away from the length of the single bar as shown in the figure below.

This is a magnetic phenomenon known as shape anisotropy, and the related intrinsic material property is its saturation magnetization. *See* O'Handley at 30 (discussing the magnetization of a soft magnetic material in the shape of a bar).

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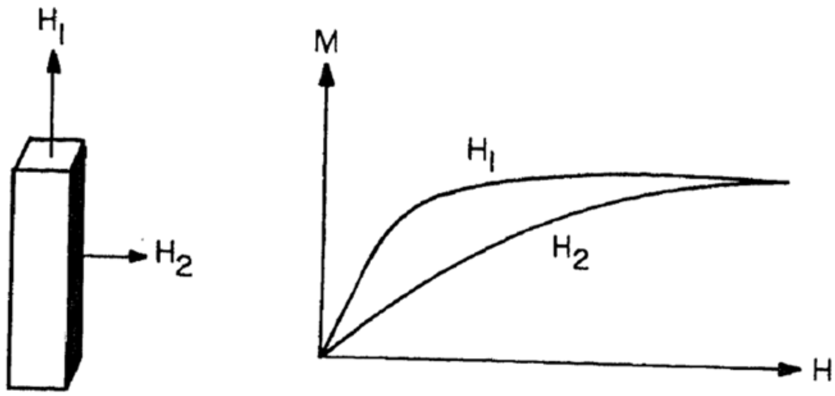
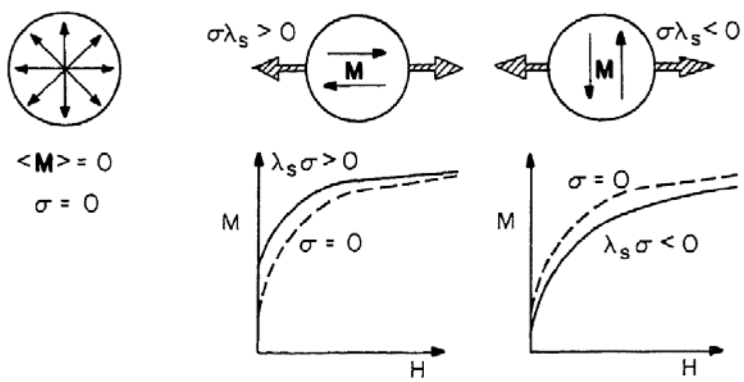


O'Handley at Fig. 2.1

49. Similarly, mechanical stress (stretching or compressing a magnetic material object) can change the magnetization direction and this is known as stress anisotropy. *See* O'Handley at 221. The related intrinsic material property is called magnetostriction.



O'Handley at Fig. 7.3

50. There are two well-known forms of intrinsic anisotropy for magnetic materials: magnetocrystalline anisotropy and induced anisotropy. *See* O'Handley at 181, 517. The latter is mostly commonly observed in materials that are non-crystalline, or that have zero or near-zero magnetocrystalline anisotropy. The directions for these anisotropies are commonly described as "easy" or "hard" and pairs of opposite directions define an "axis." The "easy axis" is a pair of opposite directions in which the field required to magnetize the material is smallest. The "hard axis" is a pair of opposite directions in which the field required to magnetize the material is the

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largest. *See, e.g.*, O'Handley at 180 (a description of the intrinsic hard and easy axis for Ni, Fe, and Co). It should be noted that the shape anisotropy effects, dependent on the shape of the single crystal sample used, are necessarily subtracted from the measured magnetization versus field data to allow observation of the intrinsic anisotropy. In the absence of an external magnetic field, shape anisotropy, and stress anisotropy, the easy axis of the material defines the directions along which magnetization prefers to lie.

51. The bcc-d magnetic materials described in the '988 Patent and in the write pole materials of the Seagate Accused Products (defined below) are "soft" magnetic materials, meaning that they are not intended to retain a permanent magnetization once the field required to magnetize the materials is removed. The magnetic behavior of soft magnetic materials are determined by multiple factors, such as extrinsic factors (e.g. shape, external field, and stress) and intrinsic factors (e.g., crystal structure, pair ordering). For example, if the sample used for the Ni magnetization versus field data measurements shown in Figure 6.1(b) of O'Handley (below) had been formed as a long cigar shaped object with the cigar length along the [100] direction, that would be the easiest direction in which the object could be magnetized, not because the material properties have been altered, but because the shape of the object has changed.

52. Crystal structures showing easy and hard magnetization directions for iron (bcc), nickel (fcc), and cobalt (hcp) are shown below. *See also, e.g.*, O'Handley at 179-183. There can be families of equivalent directions for the hard and easy axis. For example, the figure below indicates the [100] as an easy axis for bcc Fe, and all six of the <100> directions are similarly preferred for the magnetization to lie in. In an iron cobalt (FeCo) alloy with 65% Fe and 35% Co with a bcc crystal structure, the <100> directions are easy axes. *See* O'Handley at 189.

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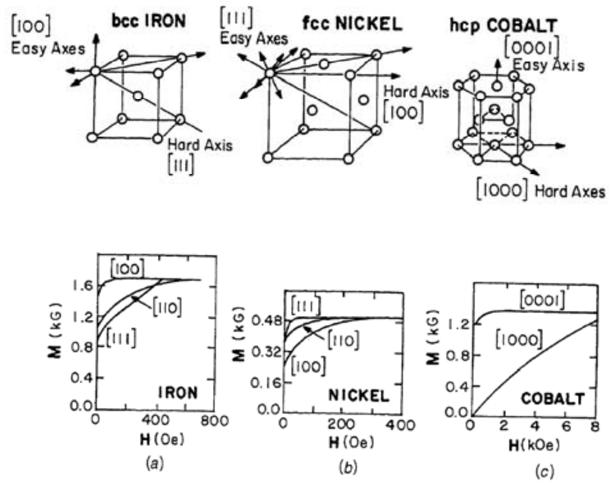

O'Handley at 180, Fig. 6.1.

53. Magnetic anisotropy due to shape can result in a higher magnetic field being needed to fully magnetize an object in a particular direction. This magnetic field associated with the shape of the object is known as the demagnetization field, as it opposes any external field that would magnetize the object. This demagnetization field can be calculated from $H_{demag} = N_d M$, where M is the object's magnetization in a given direction (having a maximum value of M_s, the saturation magnetization of the material) and N_d is the shape dependent demagnetization factor. *See* O'Handley at 38-43. The shape dependent demagnetization field and demagnetization factor tend to be small in a direction for which the object's dimension is large, and large in a direction for which the object's dimension is small, as shown in Figure 2.1 above from O'Handley. For typical magnetic thin films, a film's in-plane dimensions are more than 10,000 times greater than the film's thickness, and N_d is typically taken as zero for directions in the plane of the film and as one in the direction perpendicular to the plane of the film. *See* SEA02304935; SEA02304935 at 947-48. For such a thin film of a 2.4T material, the demagnetization field at saturation in the film in-plane directions is zero while the demagnetization field at saturation in the direction perpendicular to the film would be very large (24,000 Oe). Accordingly, for soft magnetic thin

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films it is typical that shape demagnetization effects are absent in the plane of the film. Therefore, assuming a large area thin film and either no applied stress or stress that is the same for all in-plane directions, the in-plane magnetic anisotropy due to shape effects for a soft magnetic thin film is zero, and there will be a hard axis with a very large shape-associated anisotropy perpendicular to plane. This arrangement would be well known by a person having ordinary skill in the art. Accordingly, a person having ordinary skill in the art would understand that the '988 patent concerns the intrinsic, magnetocrystalline in-plane anisotropy and magnetization of thin films, as opposed to anisotropy and magnetization perpendicular to the plane. This is also the appropriate context for most thin film magnetic property measurements, *e.g.,* BH looper measurements. However, for films having in-plane dimensions only 100 times greater than their thickness, the in-plane shape dependent demagnetization effects can be significant. For example, an in-plane demagnetization field of 1,500 Oe was predicted for a circular disk of a write pole material with a diameter of 5 □m. *See* SEA02304935 at 949. In this range of dimensions and for thin films that are not circular, the in-plane shape anisotropy effects can be significant to the magnetization directions of an object.

54. Uniaxial anisotropy is a well known concept in the field of magnetic materials and it can be used to describe intrinsic as well as extrinsic (shape, stress) anisotropies. It is represented by a magnetic energy density function of the form $E = K_{u0} + K_{u1}\sin^2\Theta + K_{u2}\sin^4\Theta + higher\ order\ terms$, where □ is the angle between the direction of magnetization and a physical axis. See O'Handley 183-188, S. Chikazumi, *Physics of Ferromagnetism*, Oxford University Press. P 249. In the above equation, higher order terms are neglected, and typically the second order term is also neglected. The zeroth order term has no meaning for anisotropic properties because it is independent of angle. These simplifications result in the common usage

of $E = K_u \sin^2(\square)$ to describe uniaxial anisotropy associated with the magnetization direction in the plane of a polycrystalline soft thin film. *See* Jan Smit (Ed.), MAGNETIC PROPERTIES OF MATERIALS, McGraw-Hill (1971) at Chapter 8, S. Middelhoek, THIN FILMS at 286; R.S. Teeble and D. J. Clark, MAGNETIC MATERIALS, Wiley-Interscience (1969) at 25-28; R.L. Comstock, INTRODUCTION TO MAGNETIC MATERIALS AND MAGNETIC RECORDING, Wiley-Interscience (1999), at 197-198; B. D. Cullity, INTRODUCTION TO MAGNETIC MATERIALS, Addison-Wesley (1972) at 363, 428.

55. The behavior of trigonometric functions, such as sin, cos, tan, $\sin^2$, and $\cos^2$, is very well known to engineers and scientists. Specifically, it is very well known that the function, $\sin^2(\square)$, has a single maxima and a single minima in 180 degrees of rotation from any starting point. Hence, it would also be very well known that multiplying $\sin^2(\square)$, by a constant factor, such as K_u, would also have a single maxima and a single minima in 180 degrees of rotation. A person with ordinary skill in the art would understand "uniaxial" refers to having an energy density function of $K_u \sin^2(\square)$ and in the context of the magnetization direction of soft magnetic thin films would mean that the magnetic energy density of a "uniaxial" material would have a single maxima and a single minima as the magnetization is rotated 180 degrees from a fixed axis. The use of "uniaxial" in magnetic materials textbooks to describe the in-plane magnetization behavior of a soft magnetic thin film was typically attributed to the presence of a pair-ordering induced anisotropy, as the broken symmetry mechanism of the '988 patent was not yet known. *See* Jan Smit (Ed.), MAGNETIC PROPERTIES OF MATERIALS, McGraw-Hill (1971) at Chapter 8, S. Middelhoek, THIN FILMS at 286; R.S. Teeble and D. J. Clark, MAGNETIC MATERIALS, Wiley-Interscience (1969) at 25-28; R.L. Comstock, INTRODUCTION TO MAGNETIC MATERIALS AND

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MAGNETIC RECORDING, Wiley-Interscience (1999), at 197-198; B. D. Cullity, INTRODUCTION TO MAGNETIC MATERIALS, Addison-Wesley (1972) at 363, 428.

56. Isotopic and anisotropic magnetic materials may have one or more magnetic domains within them. Magnetic domains are regions within a magnetic material in which the magnetization is aligned in a uniform direction. Magnetic domains may move and change with the presence of an applied field. *See, e.g.*, Smith, Neil, *Domain Theory Model for Magnetic Thin Films*, IEEE TRANS. ON MAGNETICS, 24:6, 2380-82 (Nov. 1988). Magnetic domains in thin film materials can be observed with tools such as magnetic force microscopy ("MFM"), magneto-optic Kerr effect ("MOKE") microscopy, and spin-polarized scanning electron microscopy ("SEM"). However, the domain structure and particular magnetization direction in a magnetic domain of a thin film material does not indicate whether that material has uniaxial anisotropy or the location of any easy or hard axis (or axes) for an anisotropic magnetic material. *See, e.g.*, Mitsuoka, K., et al., *Magnetic Domains of Permalloy Films for Magnetic Recording Thin Film Heads Observed by Spin-Polarized SEM*, IEEE TRANS. ON MAGNETICS, MAG-23:5 2155-57 (Sept. 1987); SEA03128955 at 975-76; Hubert, Alex and Manfred Ruhrig, *Micromagnetic analysis of thin-film elements (invited),* J. OF APPLIED PHYSICS, 69, 6072-73 (1991), Fig. 4. For example, the figure below shows multiple distinct magnetic domains with different magnetization directions in a uniaxial thin film material. The tendency of the magnetization to form a domain in which it lies parallel to the edge of a magnetic film is well known and commonly referred to as "closure" domain formation. As shown below, domains can be formed with the magnetization parallel to, perpendicular to, or at an intermediate angle to the uniaxial anisotropy axis of the material.

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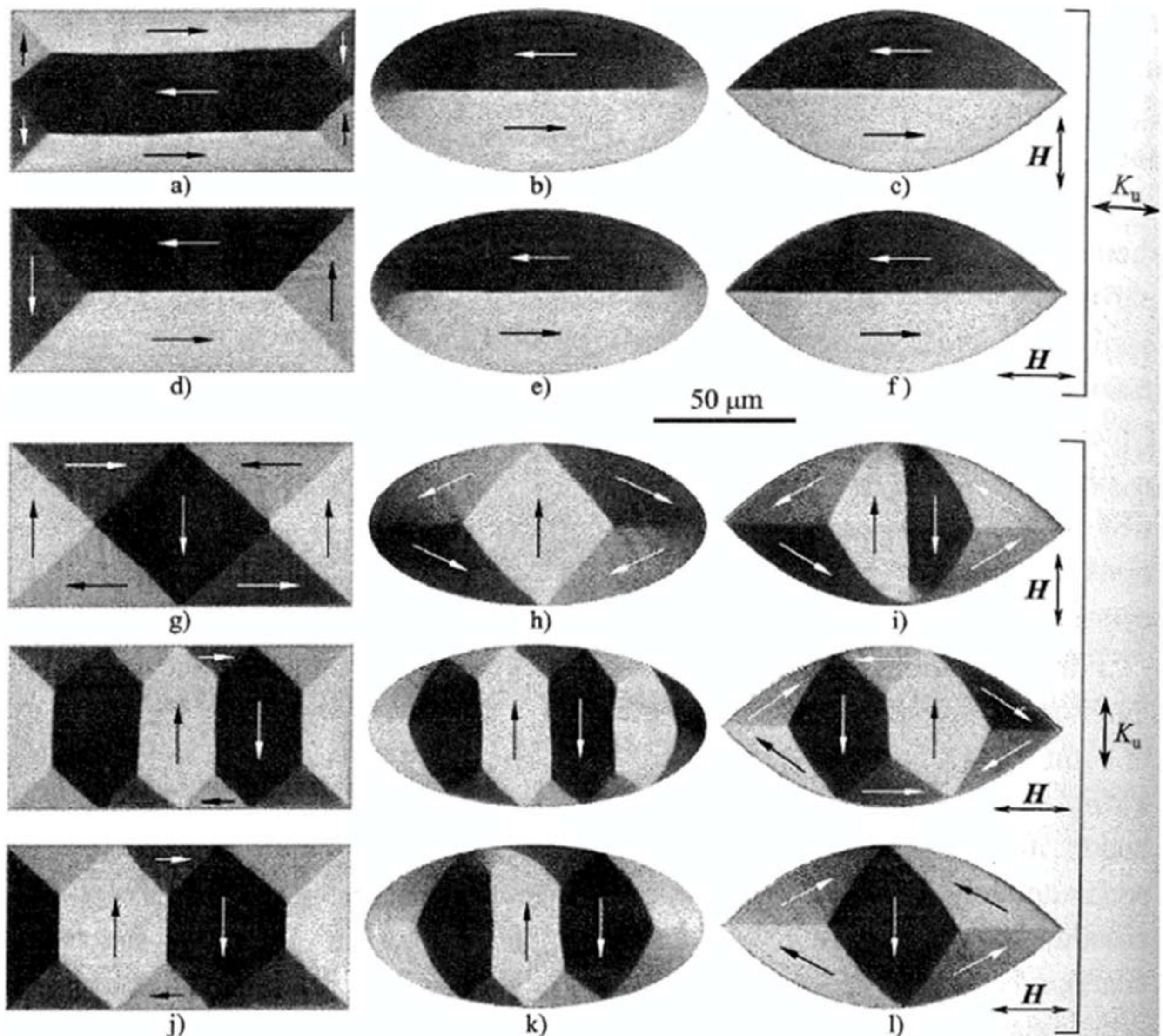

Fig. 5.71 Demagnetized states of various thick film elements (Permalloy = $Ni_{81}Fe_{19}$ of 240 nm thickness). The particles differ in their shape, and in the orientation of their easy axis relative to the particle axis. The resulting demagnetized states depend markedly on the alternating field axes used in the demagnetizing procedure. Interestingly, this is not true for elliptical and pointed shapes with a longitudinal easy axis (b−e, c−f). Different patterns can be formed under the same conditions as shown in the *last two lines*, which apply to transverse easy axes and longitudinal a.c. fields. (Samples: courtesy *M. Freitag*, Bosch, Stuttgart. Samples of this set are used throughout this section unless otherwise stated)

SEA02304935 at 955 (citing Alex Hubert and Rudolf Schafer, MAGNETIC DOMAINS: THE ANALYSIS OF MAGNETIC MICROSTRUCTURES, at 464 (2000) at Fig. 5.71).

For the write pole, the thin-film shape is more complex and not rectangular, however it is desirable for the write pole to return to a reproducible domain configuration when the external

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field for writing is removed to minimize inadvertent erasure. SEA01047774 at 786. A write pole material with uniaxial anisotropy aids this effort to minimize inadvertent erasure, or erase after write, significantly. *See* Kao, Andrew S. and Prakash Kasiraj, *Effect of Magnetic Annealing on Plated Permalloy and Domain Configurations in Thin-Film Inductive Head*, IEEE TRANS. ON MAGNETICS, 27:6 (Nov. 1991).

4. Magnetic Recording and Hard Disk Drives

57. Magnetic recording is the method used for encoding information in hard disk drives ("HDDs"). Magnetic recording is one the technologies to which the '988 patent is directed and is at issue in this case.

58. Computers store and read data in bits, or binary digits, representing either a 0 or a 1. In a simplified view of magnetic recording, a 1 might be represented by a bit of material being magnetized up, and a 0 by that bit of material being magnetized down. The state of magnetization of the bits can be read in order recover the information stored.

59. In HDDs, the magnetic material that stores the data is called a platter or a disk, which is a circular plate of magnetic material that is used to store the data as bits. The disk is divided into tracks and sectors containing areas that can be magnetized to store data, where the tracks are concentric circles and the sectors are small sections of a track.

60. In order to write data to and read data from a platter, the platter will be rapidly spun and a read/write head passed over the platter. The head moves to the track into which data will be written or read from, and the platter spins so that the correct sector lines up with the head.

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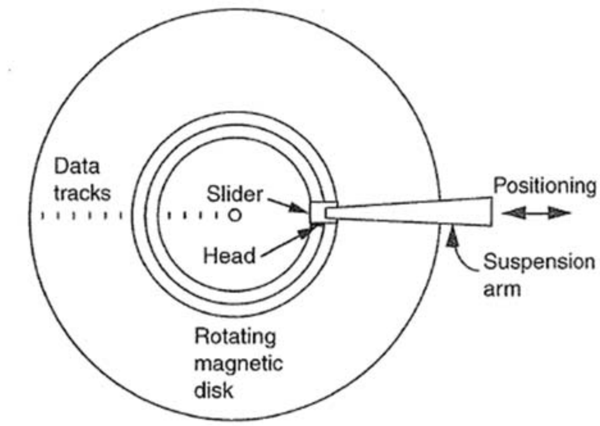
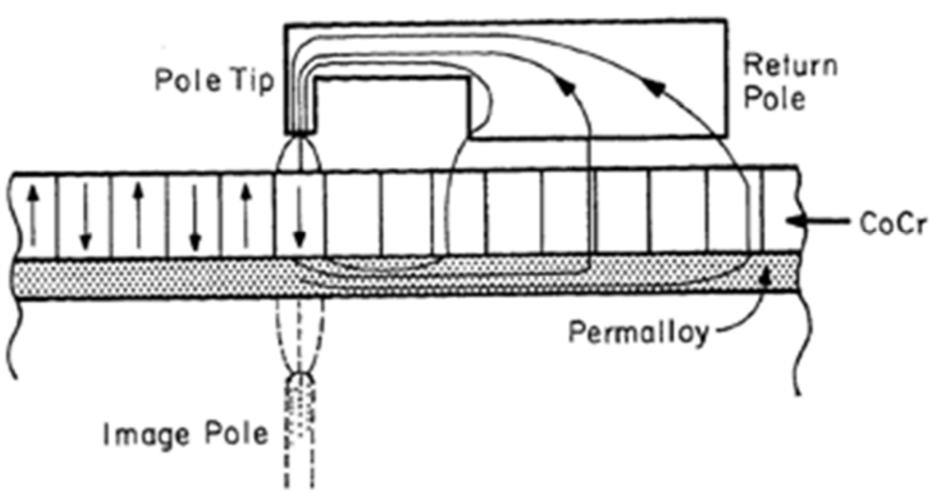


Figure 15–3 Concentric circular tracks on a disk: a positioner moves the slider containing the head to either follow a track or seek a new track.

Eric D. Daniels, MAGNETIC RECORDING: THE FIRST 100 YEARS at 232, Fig. 15-3 (1999)

61. A simplified depiction of an HDD head is shown below. In this depiction, 0s and 1s are distinguished by their differing up/down magnetic orientations. The write head orients (or "writes") each bit accordingly as either a 0 or a 1, and the read head can detect (or "read") that orientation. Basically, each bit acts like a small bar magnet, with the poles aligned in one direction for a 1 and the other for a 0.



O'Handley. Fig. 17.11

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5. Easy and Hard Axes in Magnetic Recording.

62. In magnetic materials, such as those used in hard drive write heads, it is preferable to have a preferred magnetic orientation so that when no magnetic field is applied to the head, the head material has a magnetization vector that tends to align along the magnetic easy axis. Such materials are known as magnetically anisotropic materials. In contrast, magnetically isotropic materials do not have a preferred magnetic orientation unless there is an applied external magnetic field, shape, or stress anisotropies present. In the presence of a sufficiently large external magnetic field, the magnetization vector of an anisotropic material will switch to another direction known as the magnetic hard axis. This is useful, for instance, in hard drive write (record) heads. As the write head passes over a bit in the hard drive platter, if the magnetization of the write pole is aligned in one direction, for instance, along the easy axis, then the magnetic orientation of that bit will not change and no recording takes place. This is desirable if one wishes only to read back previously recording information. If, however, the write head's magnetization is aligned along the other directions (toward or away from the bit), in this example, along the hard axis, then data will be recorded as the bit's magnetic orientation will change and thus the data represented by that orientation also changes (e.g., from a 0 to a 1). [redacted]

6. Longitudinal magnetic recording (LMR)

63. Longitudinal magnetic recording ("LMR") is a term used to refer to a recording geometry where the recording media stores data by being magnetized in the plane of the media

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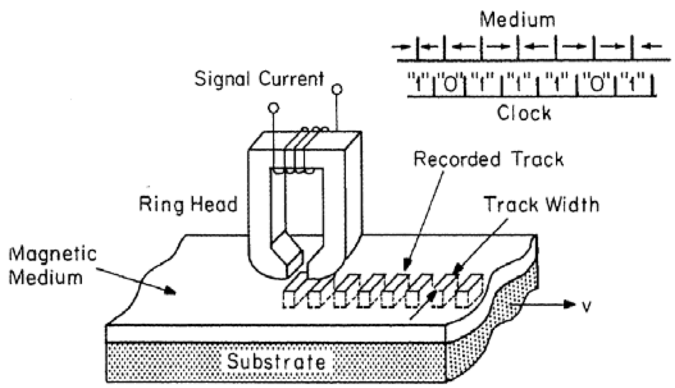
surface, e.g., left or right. To record bits on LMR media, the write head must generate a magnetic field in the plane of the surface of the recording media, as illustrated below.



O'Handley at 676, Fig. 17.2

Because bits in LMR are recording in the plane of the media, the maximum amount of bits that can be recorded on a given area of the media is lower than in perpendicular magnetic recording.

D. Perpendicular magnetic recording (PMR)

64. Perpendicular magnetic recording ("PMR") is a term used to refer to a recording geometry where the recording media stores data by being magnetized perpendicular to the plane of the media surface, e.g., up or down. To record bits on PMR media, the write head must generate a magnetic field perpendicular to the surface of the recording media, as illustrated below.

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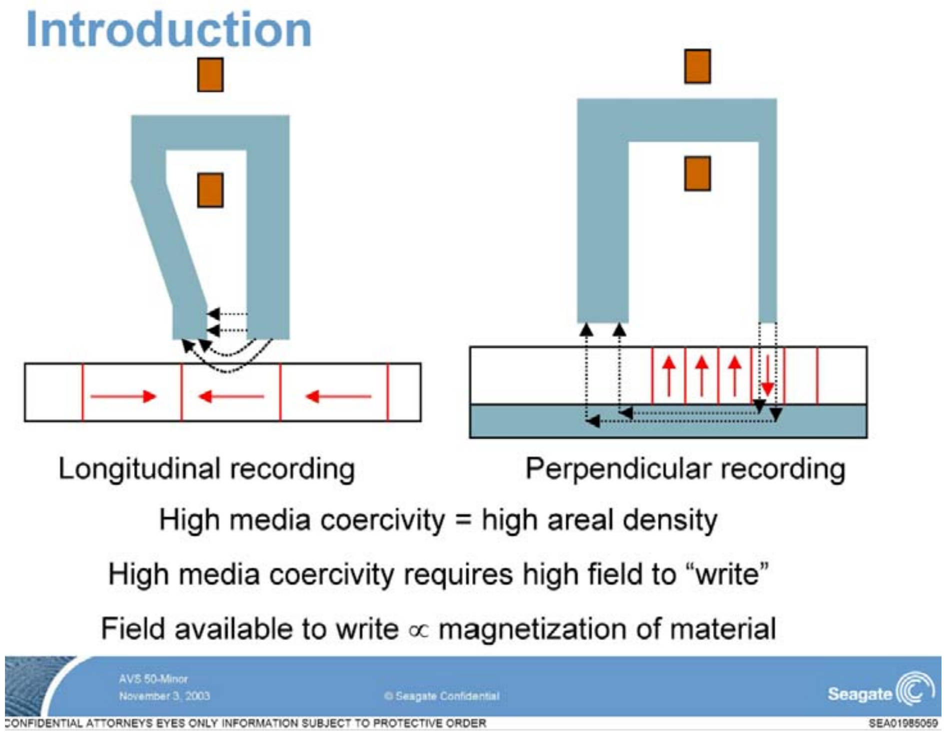

SEA01985058 at 059.

65. The use of magnetization perpendicular to the surface of the media allows more bits of data to be written onto recording media in a perpendicular configuration than is possible in a longitudinal configuration—that is, PMR hard disk drives have greater areal density than LMR hard disk drives. *See, e.g.*, SEA02549816 at 818; SEA02851751; SEA03140770 at 775; SEA00507193 at 200; SEA00521626 at 631, 669; SEA01017440 at 451; SEA01017462 at 474-475; SEA01423269 at 270, 279; SEA02372422 at 445-446. Hard disk drive customers constantly demand increasing areal density so that they may have physically small hard disk drives that hold increasingly greater amounts of data. *See, e.g.*, SEA00507193 at 199-201; SEA00521626 at 631-632, 669; SEA01423163; SEA01423269; SEA01470620; SEA02372422 at 445-446; SEA02372976 at 977-981, 990, 011; SEA02534719 at 726, 757; SEA02545926 at 931, 932; SEA02851751; SEA03140770; SEA03143770; SEA03128955 at 958, 969; SEA02401000 at 1001-1003, 1009; SEA01017440 at 450-451; SEA01017462; SEA01017514;

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SEA02374480 at 496; SEA02007789; SEA02549816 at 818, 848. Accordingly, the transition to PMR hard disk drives was supported by substantial consumer demand.

1. Requirements for PMR Write Heads

66. To access the higher areal density possible through the use of PMR hard disk drives, the industry had to adapt both the materials used in the recording media and the write heads. To maximize the benefit of recording media with smaller regions capable of being magnetized up-and-down, the industry transitioned to higher coercivity materials in the media. To write on the higher coercivity media, the industry had to transition to higher moment magnetic materials.

2. High Moment Magnetic Materials in PMR Write Heads

67. [redacted]

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[redacted]

68. [redacted]

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[redacted]

69. [redacted]

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[redacted]

70. [redacted]

1) Areal density is inversely proportional to media grain area and media grain volume when an acceptable level of media noise is held constant.

2) Media grain area is inversely proportion to media magnetic anisotropy energy density when an acceptable, constant level of thermal stability is maintained.

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3) Based on items 1 and 2 above, areal density is directly proportional to the media magnetic anisotropy energy density for systems with similar noise and thermal stability designs.

4) The media magnetic anisotropy energy density is directly proportional to the media coercivity, which is in turn directly proportional to the saturation magnetization of the write head pole material for similar write head designs.

[redacted]

71. [redacted]

72. [redacted]

[redacted]

E. Challenges in Transitioning from LMR to PMR

1. Erase After Write (EAW)

73. [redacted]

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[redacted]

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[redacted]

II. The '988 Patent and Asserted Claims

A. Overview of the '988 Patent

74. U.S. Patent No. 7,128,988, entitled "Magnetic Material Structures, Devices and Methods," was filed as a PCT application on August 29, 2002. The inventor of the '988 patent is

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David N. Lambeth. The '988 patent was initially assigned to Lambeth Systems and is presently assigned to LMS.

75. The invention of the '988 patent is directed to magnetic material structures and devices. '988 patent at 1:8-10. The '988 patent discloses "new mechanisms for controlling the magnetocrystalline anisotropy of thin magnetic films." *Id*. at 1:50-51; 14:35-47.

76. The '988 patent first discloses in the Background of the Invention details regarding the state of the art prior to the date of the invention, including the challenges associated with controlling the magnetic orientation, or anisotropy directions, in magnetic materials. *Id*. at 1:11-12:54. As the '988 patent explains, "good performance in device applications is almost always dependent upon there being a single preferred magnetic orientation or anisotropy direction and so in the manufacturing process one strives to achieve a desired uniaxial anisotropy." *Id*. at 1:45-49. However, "[m]aterials and device processing to achieve a desired orientation or anisotropy is commonly difficult and sometimes impossible" because prior to the invention of the '988 patent, "the mechanism for achieving anisotropic orientation has not been well understood." *Id*. at 1:62-66. In addition, "uniform control of the orientation of the magnetic anisotropy is often difficult to achieve and maintain in a manufacturing process where many different desired material properties must be maintained simultaneously." *Id*. at 1:66-2:3. The invention of the '988 patent reveals a mechanism for achieving such uniform control of magnetic anisotropy.

77. When a thin film material has only one easy axis and one hard axis there will be two minimums in its anisotropy energy density function which correspond to preferred directions for magnetization (180 degrees apart) and two maximums in its anisotropy energy density function which correspond to the disfavored directions for magnetization (also 180 degrees

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apart) as the magnetization is rotated 360 degrees or more in the plane of the film (about an axis that is perpendicular to the film). When a material has an anisotropy energy density function with only a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis, the material is said to have "uniaxial" anisotropy. *Id*. at 1:56-60. In order to achieve uniform control of uniaxial anisotropy in magnetic materials, the '988 patent invention takes advantage of the fact that in thin layers of materials (known as "thin films"), including magnetic materials, "thin films prefer to grow with the atoms arranged on the thin film surface to minimize the atomic bonding energy" such that "the most stable atomic crystalline surface grows when the surface atoms form the densest arrangement consistent with the crystalline structure." *Id*. at 9:15-20. This means that the crystalline structure of one material can guide the formation and direct the growth of the crystalline structure of an overlying layer of material grown on the underlying layer. *Id*. at 9:38-10:23. The underlying material is referred to as an atomic template. *Id*. at 14:48-51.

78. The '988 patent discloses atomic templates that guide the formation and direct the growth of overlying magnetic layers in order to contribute to the desired uniaxial anisotropy. *See, e.g., id*. at 14:48-61, 23:38-41, 24:60-25:10, 25:57-64; 26:21-25, 26:37-40. Specifically, the '988 patent discloses a template with a fcc or fcc derivative ("fcc-d") crystal lattice structure with (111) crystalline texture (equivalently, a hcp crystal lattice structure with (0002) crystalline texture as both of these present a crystal plane having the close-packed hexagonal arrangement of atoms to the layer above). *Id*. at 14:55-62. The '988 patent further discloses growing over this template a layer (or layers) of magnetic material that has a bcc or bcc derivative ("bcc-d") crystal lattice structure. As the '988 patent explains, when such a material is grown over the atomic template, there are a limited number of ways in which that bcc-d material can be oriented,

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namely, six. *Id*. at 14:48-61. One of the six possible crystallographic structural orientations of the overlying material is referred to as one of six possible crystallographic "variants." *Id*. When all six of these variants occur in equal amounts, the structure is symmetrical. However, when fewer than all six variants occur or when the amounts of the variants are not equal (in a given volume), the structure is "symmetry broken." *Id*. at 23:38-41. This symmetry breaking can result in a material with intrinsic uniaxial anisotropy. See, e.g., *id*. at 24:60-25:10, 25:57-64; 26:21-25, 26:37-40. External sources of anisotropy such as stress anisotropy (such as that imposed upon the film by the substrate) and shape anisotropy associated with the shape of the object from which the material is made, are distinct from the focus of the '988 patent, which concentrates on and claims the invention of uniaxial anisotropic bcc-d thin film materials as a result of symmetry breaking. *See id*.

B. Asserted Claims of the '988 Patent

79. I understand that LMS asserts that the Seagate Accused Products infringe claims 1, 3, 6, 7, 9, 17, 19, 27, 28, and 29 of the '988 patent. Claims 1 and 27 are independent claims. Claims 3, 6, 7, 9, 17, and 19 are all dependent claims that are each dependent on claim 1. Claims 28 and 29 are both dependent claims that are each dependent on claim 27.

80. Independent claim 1 provides:

> A magnetic material structure comprising:
>
> a substrate;
>
> at least one bcc-d layer which is magnetic, forming a uniaxial symmetry broken structure; and
>
> at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer.

81. Dependent claim 3 provides:

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> The magnetic material structure recited in claim 1, wherein a surface of said substrate is amorphous or polycrystalline.

82. Dependent claim 6 provides:

> The magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is formed from a fcc-d or hcp crystalline material.

83. Dependent claim 7 provides:

> The magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is magnetic.

84. Dependent claim 9 provides:

> The magnetic material structure according to claim 1, further comprising:
>
> a second layer providing a (111) textured hexagonal atomic template, wherein said second layer is magnetic.

85. Dependent claim 17 provides:

> The magnetic material structure recited in claim 1, wherein said bcc-d layer forming a uniaxial symmetry broken structure is composed of Fe or FeCo or an alloy of Fe or FeCo.

86. Dependent claim 19 provides:

> The magnetic material structure recited in claim 1, wherein the layer material forming said (111) textured hexagonal atomic template is composed of Ag, Al, Au, Cu, fcc-Co, fcc-CoCr, Ir, Ni, NiFe, Pt, Rh, Pd, hcp-Co, Gd, Re Ru, Tb, Ti or alloys of one of these materials combined with at least one element.

87. Independent claim 27 provides:

> A magnetic device having incorporated therein a magnetic material structure comprising:
>
> a substrate;
>
> at least one bcc-d layer which is magnetic, forming a uniaxial symmetry broken structure; and
>
> at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer.

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88. Dependent claim 28 provides:

> The magnetic device recited in claim 27, wherein the device is a magnetic data storage system.

89. Dependent claim 29 provides:

> The magnetic device recited in claim 27, wherein the device is a data storage magnetic recording transducer.

C. Claim Construction of the '988 Patent

90. It is my understanding that the Court issued its Memorandum Order construing claims in this matter October 18, 2017 ("Claim Construction Order"). I have used the claim constructions for the construed terms of the '988 patent, as set forth in the Claim Construction Order, to formulate my opinions set forth in this Report.

91. Specifically, I understand that the Court construed eight terms from the claims of the '988 patent as reflected in the table below. I understand that the Court resolved disputes between the parties to arrive at the constructions for "atomic template," "[layer] providing a (111) textured hexagonal atomic template," "uniaxial," "symmetry broken structure," "uniaxial symmetry broken structure," and "variant(s)/orientational variant(s)." I understand that the parties agreed on and the Court subsequently ordered the constructions for "bcc-d" and "fcc-d."

Term	Construction
"atomic template"	An atomic pattern upon which material is grown and which is used to direct the growth of an overlying layer
"[Layer] providing a (111) textured hexagonal atomic template"	Layer that is predominately (111) hexagonal and that provides an atomic template
"Uniaxial"	Having an anisotropy energy density function with only a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis
"Symmetry broken structure"	A structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system

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Term	Construction
"Uniaxial symmetry broken structure"	A structure that is uniaxial as a result of the structure being symmetry broken
"Variant/orientational variant" "Variants/orientational variants"	One of a set of possible crystal orientations Two or more of a set of possible crystal orientations
"bcc-d"	Either a body centered cubic or a body centered cubic derivative crystal structure
"fcc-d"	Either a face centered cubic or a face centered cubic derivative crystal structure

See Claim Construction Order, at 7-8.

92. None of the other terms in claims 1, 3, 6, 7, 9, 17, 19, 27, 28, and 29 of the '988 patent have been construed by the Court. I have applied the plain and ordinary meaning according to a person having ordinary skill in the art to all non-construed terms.

III. The Seagate Accused Products

93. The Seagate Accused Products are PMR hard disk drives and products containing hard disk drives that were sold on or after May 2010.

94. Each of the Seagate Accused Products contains heads that have both read and write functionality designed for use in PMR. A head (or multiple heads) is mounted on a head gimbal assembly ("HGA") within the hard disk drive, which in turn is combined into a head stack assembly ("HSA") containing multiple heads, depending on the particular configuration of the Seagate Accused Product. Annotated photographs taken during the process of tearing down a Seagate Accused Product, specifically sample S0GPPC, are shown below in Sections VI.1.a. and VI.1.c..

95. [redacted]

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[redacted]

[redacted]

[redacted]

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[redacted]

A. Overview of Seagate's PMR Write Heads

96. The write head itself is composed of multiple thin films of material. The material with the highest magnetic moment is incorporated as part of a material stack that is referred to by Seagate as the Write Pole or WP Material. The highest magnetic moment material in the Write Pole of all of the Seagate Accused Products is 2.4T FeCo, which writes to the recording media and is exposed to the media at the air bearing surface ("ABS").

97. [redacted]. The specific write pole configurations associated with each head type are described further below.

1. [redacted] Write Heads

98. [redacted]

> [redacted]

[redacted]

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2. [redacted] Write Heads

99. [redacted].

3. [redacted] Write Heads

100. [redacted]

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[redacted]

B. The Seagate Accused Products

101. Seagate makes, uses, sells, offers for sale, and imports to the United States various hard disk drives and hard disk drive-containing products that utilize PMR and include at least one of the [redacted] write heads. Together, these products are the Seagate Accused Products.

1. The Seagate Accused Products Containing [redacted] Write Heads ([redacted] Products")

102. [redacted]

103. [redacted]

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[redacted]

[redacted]

2. The Seagate Accused Products Containing [redacted] Write Heads ("[redacted] Products")

104. [redacted]

105. [redacted]

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[redacted]

3. The Seagate Accused Products Containing [redacted] Write Heads ("[redacted] Products")

106. [redacted]

107. [redacted]

[redacted]

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[redacted]

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[redacted]

IV. Damages-Related Opinions

1. Opinion No. 1: The following patents are marginally technologically comparable to the '988 patent: U.S. Patent Nos. 5,453,315; 5,483,025; 5,490,027; 5,557,488.

108. I have reviewed U.S. Patent Nos. 5,453,315; 5,483,025; 5,490,027; 5,557,488 (hereinafter referred to as the "Censtor Patents"). It is my opinion that the Censtor Patents are marginally technologically comparable to the '988 patent. Like the '988 patent, the Censtor Patents are related to technology intended for increasing areal density for magnetic recording. In particular, all of the Censtor Patents are directed to contact recording. *See, e.g.*, '315 patent at 5:19-49; '025 patent at 4:54-5:14, 6:62-7:10; '027 patent at Abstract, 3:53-56, 5:57-63, 6:16-18, 14:11-44, 14:63-15:8; '488 patent at Abstract, 16:11-13, 16:26-42; *see generally* '315 patent; '025 patent; '027 patent; '488 patent. While contact recording was never realized in commercial hard disk drives, it was intended to increase areal density for magnetic recording by bringing the write head closer—in fact, in contact with--the media of the hard disk drive. Moreover, the Censtor Patents include invention disclosures that do not require substantial additional development time and effort. *See generally* '315 patent; '025 patent; '027 patent; '488 patent.

2. [redacted]

109. [redacted]

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[redacted]

3. Opinion No. 3: U.S. Patent No. 4,949,039 is not technologically comparable to the '988 Patent.

110. I have reviewed U.S. Patent No. 4,949,039. It is my opinion that the '039 patent is not technologically comparable to the '988 patent. In particular, the '039 patent discloses a theoretical GMR design that would have required substantial additional development time and effort before it could be implemented into commercial hard disk drives. *See generally* '039 patent. The '039 patent does not disclose the need for, or methodology for, read heads to be linear through hysteresis reduction and elimination of domain wall movement, which was a necessary technological development during the transition from AMR to GMR read head technologies that allowed GMR technology to be implemented into commercial hard disk drives. *See generally* '039 patent.

4. Opinion No. 4: U.S. Patent No. 5,686,838 is not technologically comparable to the '988 patent.

111. I have reviewed U.S. Patent No. 5,686,838. It is my opinion that the '838 patent is not technologically comparable to the '988 patent. In particular, the '838 patent discloses a theoretical design that would have required substantial additional development time and effort before it could be implemented into commercial hard disk drives. *See generally* '838 patent. The '838 patent does not disclose the methodology for read heads to be linear through hysteresis reduction and elimination of domain wall movement, which was a necessary technological development during the transition from AMR to GMR read head technologies that allowed GMR technology to be implemented into commercial hard disk drives. *See generally* '838 patent.

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5. Opinion No. 5: U.S. Patent Nos. 4,673,996 ('996 patent), 4,870,519 ('519 patent), 5,404,256 ('256 patent), and 5,726,831 ('831 patent) are not technologically comparable to the '988 patent.

112. I have reviewed U.S. Patent Nos. 4,673,996, 4,870,519, 5,404,256, and 5,726,831 (hereinafter referred to as the "White Patents"). It is my opinion that the White Patents are not technologically comparable to the '988 patent. In particular, the White Patents are directed to mechanical designs related to the geometry of the air bearing surface of a head and are not directed to technology intended for increasing areal density for magnetic recording. *See generally* '996 patent; '519 patent; '256 patent; '831 patent. In contrast, the '988 patent is related to technology intended for increasing areal density for magnetic recording. *See generally* '988 patent; *see supra* Sections I.D., I.E., and II.

6. Opinion No. 6: The following patents are not technologically comparable to the '988 patent: U.S. Patent Nos. 5,786,038; 6,083,570; 6,165,616.

113. I have reviewed U.S. Patent Nos. 5,786,038, 6,083,570, and 6,165,616 (hereinafter referred to as the "Syndia Patents"). It is my opinion that the Syndia patents are not technologically comparable to the '988 patent. In particular, the Syndia Patents are related to a diamond-like carbon film, and while diamond-like carbon films can be used as a protective coating of the bottom of a head in a hard disk drive to protect against corrosion or wear, all of the Syndia Patents require an intermediary layer, which would add additional thickness that would not be desirable or applicable in the magnetic recording setting. *See, e.g.*, '038 patent at 4:23-55; '570 patent at Abstract, 3:54-59, 4:18-45, 6:8-24; '616 patent at Abstract, 1:10-20, 4:50-65, 6:34-47, 9:65-10:10, 10:18-30, 10:33-11:11, 12:1-16; *see generally* '038 patent; '570 patent; '616 patent. In contrast, the '988 patent is directed to magnetic recording technologies and does not relate to protective coatings. *See generally* '988 patent. Additionally, the Syndia Patents are not

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related to technology intended for increasing areal density for magnetic recording. *See generally* '038 patent; '570 patent; '616 patent. In contrast, the '988 patent is related to technology intended for increasing areal density for magnetic recording. *See generally* '988 patent; *see supra* Sections I.D., I.E., and II.

7. Opinion No. 7: The following patents are not technologically comparable to the '988 patent: U.S. Patent No. 4,638,383.

114. I have reviewed U.S. Patent No. 4638,383. It is my opinion that the '383 patent is not technologically comparable to the '988 patent. In particular, the '383 patent discloses using an "open-loop" servo, which would be used in a low areal density setting. *See, e.g.*, '383 patent at Abstract, 2:44-49; *see generally* '383 patent. Therefore, the '383 patent is not related to technology intended for increasing areal density for magnetic recording, in contrast, to the '988 patent. *See generally* '988 patent; *see supra* Sections I.D., I.E., and II.

8. Opinion No. 8: The following patents are not technologically comparable to the '988 patent: U.S. Patent Nos. 4,519,010; 4,535,373; 4,922,406; 5,216,557; 5,424,887; 5,446,610; 5,557,487; 5,661,351; 5,708,539; 5,729,403; 5,777,822; 5,796,548; 5,801,900; 5,864,443; RE 32,702; RE 34,412; RE 37,058.

115. I have reviewed U.S. Patent Nos. 4,519,010; 4,535,373; 4,922,406; 5,216,557; 5,424,887; 5,446,610; 5,557,487; 5,661,351; 5,708,539; 5,729,403; 5,777,822; 5,796,548; 5,801,900; 5,864,443; RE 32,702; RE 34,412; RE 37,058 (hereinafter referred to as the "Papst Patents"). It is my opinion that the Papst patents are not technologically comparable to the '988 patent. In particular, the Papst patents are directed to motor designs, which is not technologically comparable to the technology intended to increase areal density for magnetic recording disclosed in the '988 patent. *See generally* '010 patent; '373 patent; '406 patent; '557 patent; '887 patent; '610 patent; '487 patent; '351 patent; '539 patent; '403 patent; '822 patent; '548 patent; '900 patent; '443 patent; '702 patent; '412 patent; '058 patent. Therefore, the Papst Patents are not

related to technology intended for increasing areal density for magnetic recording. *See generally* ‘010 patent; ‘373 patent; ‘406 patent; ‘557 patent; ‘887 patent; ‘610 patent; ‘487 patent; ‘351 patent; ‘539 patent; ‘403 patent; ‘822 patent; ‘548 patent; ‘900 patent; ‘443 patent; ‘702 patent; ‘412 patent; ‘058 patent.

9. Opinion No. 9: The write pole configurations discussed herein, specifically [redacted] (*see supra* Section III.B.), together with other components that make up Seagate’s HGAs, constitute a functional unit.

116. [redacted]

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[redacted]

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10. Opinion No. 10: The write pole configurations discussed above, specifically [redacted] (*see supra* Section III.B.), are parts of a complete machine, which in this case are Seagate's HGAs.

117. [redacted]

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11. Opinion No. 11: The '988 patented invention is critical to enabling Seagate to commercialize HDDs with PMR functionality.

118. [redacted]

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12. Opinion No. 12: The '988 patented invention is critical to enabling Seagate to commercialize HDDs with write heads capable of writing on drives with higher areal density.

119. As described above, the '988 patented invention is critical to enabling Seagate to commercialize HDDs with PMR functionality. *See supra* Sections I.D., I.E., and II. To access the higher areal density possibly through the use of PMR hard disk drives, the industry had to adapt both the materials used in the recording media and the write heads. To maximize the benefit of recording media with smaller regions capable of being magnetized up-and-down, the industry transitioned to higher coercivity materials in the media. To write to higher coercivity media, higher magnetization materials are necessary in the write pole of the write head to create a sufficiently strong magnetic field to change the magnetization of the recording media. The '988 patent discloses atomic templates that guide the formation and direct the growth of overlying magnetic layers in order to contribute to uniaxial anisotropy in the write head through symmetry breaking, therefore permitting the presence of higher magnetization materials in the write pole of the write head.

13. Opinion No. 13: There are no acceptable non-infringing alternatives to the '988 patented invention.

120. I am not aware of any acceptable non-infringing alternatives to the '988 patent invention. I understand that Seagate contends "all Seagate products" are non-infringing alternatives. *See* Seagate's Answers to LMS's 5th Set of Interrogatories, Interrogatory No. 22, dated February 21, 2018, at 21-22. I disagree that Seagate Accused Products are non-infringing alternatives because, as set forth in detail below, the Seagate Accused Products infringe the Asserted Claims of the '988 patent. *See* Sections III.B., VI., VII., and VIII.

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V. Indirect Infringement

1. Opinion No. 14: Seagate induces third parties to infringe the ’988 patent

121. [redacted]

122. Seagate’s website contains material providing information regarding the Seagate Accused Products, including information touting their alleged benefits. *See, e.g.*, https://www.seagate.com/www-content/product-content/hdd-fam/seagate-archive-hdd/en-us/docs/archive-hdd-ds1834-5c-1508us.pdf; https://www.seagate.com/www-content/product-content/barracuda-fam/barracuda-new/files/barracuda-ds-1900-3-1608us.pdf; https://www.seagate.com/www-content/product-content/seagate-business-fam/business-storage-8-bay-rackmount-nas/en-us/docs/business-storage-8-bay-rackmount-nas-ds1799-1-1307us.pdf; https://www.seagate.com/www-content/datasheets/pdfs/ent-cap-3-5-hdd-12tb-v7DS1925-1M-1703US-en_US.pdf; https://www.seagate.com/www-content/datasheets/pdfs/game-drive-for-ps-dsg-migDS1898-2-1608-WW-en_CA.pdf; https://www.seagate.com/www-content/datasheets/pdfs/laptop-hdd-4tbDS1887-4-1603US-en_US.pdf; https://www.seagate.com/www-content/datasheets/pdfs/mobile-hddDS1861-2-1603-en_US.pdf; https://www.seagate.com/files/docs/pdf/datasheet/disc/ds_momentus_7200_2.pdf;

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https://www.seagate.com/www-content/product-content/video_3_5_pipeline-fam/pipeline-hd/en-us/docs/video3-5-hdd-ds1783-3-1309us.pdf; http://www.hammer-drive.com/assets/uploads/downloads/drive-selector/VIDEO%202.5%20HDD.pdf; https://www.seagate.com/www-content/product-content/skyhawk/files/skyhawk-ds-1902-3-1608us.pdf

123. [redacted] Seagate's encouragement includes advertising and marketing regarding the Seagate Accused Products and presentations of the Seagate Accused Products at industry events and conference, among other activities. *See, e.g.* http://wheretobuy.seagate.com/?language=en-us; https://www.seagate.com/consumer/; https://www.seagate.com/consumer/backup/; https://www.seagate.com/consumer/play/; https://www.seagate.com/consumer/upgrade/; https://www.seagate.com/our-story/brand/; https://www.seagate.com/internal-hard-drives/; https://www.seagate.com/internal-hard-drives/hdd/; https://www.seagate.com/internal-hard-drives/creative-professionals/; https://www.seagate.com/enterprise-storage/; https://www.waybackmachine.org/web/20130315141757/http://www.seagate.com/internal-hard-drives/desktop-hard-drives/desktop-hdd/; http://www.adsoftheworld.com/media/print/seagate_popcorn; http://www.adsoftheworld.com/media/print/seagate_cello; https://www.youtube.com/watch?v=DaYpYk0kVpQ; https://www.youtube.com/watch?v=_u22-XLej6Y; https://www.youtube.com/watch?v=cX329JK3iz8; https://www.youtube.com/watch?v=lijeM3b5zvQ; https://www.youtube.com/watch?v=y4glYAbVQA8;

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https://www.youtube.com/watch?v=frNc8FqmyXo;

https://www.youtube.com/watch?v=dX6ZbvJRBDc;

https://www.youtube.com/watch?v=18d8BnIxC1g.

124. Seagate admitted that it became aware of the '988 patent at least as early as January 9, 2015. See Seagate's Response to Interrogatory No. 14 (Dec. 11, 2017) at 13; SEA03336364; Pechman 30(b)(6) Dep Tr. at 73:4-10.

VI. [redacted] Direct Infringement

1. Opinion No. 15: The [redacted] Products Infringe Claim 1 of the '988 Patent

125. It is my opinion that the [redacted] Products infringe claim 1 of the '988 patent. It is my opinion that every element of claim 1 is literally met by each of the [redacted] Products. I explain the foundation for my opinion on an element-by-element basis below. Alternatively, it is my opinion that the [redacted] Products infringe claim 1 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents. Accordingly, claim 1 is infringed by the [redacted] Products where "uniaxial" is met pursuant to the doctrine of equivalents and all other limitations are literally present.

126. I understand that the Court construed certain terms in claim 1 of the '988 patent. Specifically, I understand that the Court construed six terms from the claims of the '988 patent as reflected in the table below.

Term	Construction
"atomic template"	An atomic pattern upon which material is grown and which is used to direct the growth of an overlying layer
"[Layer] providing a (111) textured hexagonal atomic template"	Layer that is predominately (111) hexagonal and that provides an atomic template
"Uniaxial"	Having an anisotropy energy density function with only a single maximum and a single

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Term	Construction
	minimum as the magnetization angle is rotated by 180 degrees from a physical axis
"Symmetry broken structure"	A structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system
"Uniaxial symmetry broken structure"	A structure that is uniaxial as a result of the structure being symmetry broken
"Variant/orientational variant" "Variants/orientational variants"	One of a set of possible crystal orientations Two or more of a set of possible crystal orientations
"bcc-d"	Either a body centered cubic or a body centered cubic derivative crystal structure
"fcc-d"	Either a face centered cubic or a face centered cubic derivative crystal structure

See Claim Construction Order, at 7-8. I have applied the Court's constructions for all construed terms in my infringement analysis. I have applied the plain and ordinary meaning according to a person having ordinary skill in the art to all non-construed terms.

a) To the extent the preamble to claim 1, "[a] magnetic material structure comprising" is limiting, it is met by the [redacted] Products

127. The preamble to claim 1 recites "[a] magnetic material structure comprising."

128. I understand that the preamble to a patent claim is generally not limiting. I further understand that Seagate has not sought construction of the preamble to claim 1 of the '988 patent and has not asserted that it is limiting, nor has the Court construed the preamble of claim 1 of the '988 patent to be limiting. Nevertheless, each of the [redacted] Products include a magnetic material structure.

129. [redacted]

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[redacted]

130. [redacted]

131. Reverse engineering performed at my direction on a representative [redacted] Product, specifically a hard disk drive bearing Seagate model no. ST32000645SS 6 TB and referred to as sample S0GPPC, shows that the [redacted] Products include a magnetic material structure in the write pole. [redacted] An image of

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this [redacted] Product, sample S0GPPC, before it was torn down is shown below. All sliders reverse engineered from the same sample product are referred to by the same sample name, e.g., S0GPPC.

Seagate Constellation ES.2 Hard Drive
ST32000645SS

132. Reverse engineering was also performed at my direction on a second representative [redacted] Product, specifically a hard drive produced by Seagate bearing Seagate model no. ST3000NM0023 3TB and referred to as sample, S2MMMC. I understand that Sample S2MMMC was produced to LMS by Seagate during fact discovery in this case. [redacted]

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[redacted] An image of this [redacted] Product, sample S2MMMC, before it was torn down is shown below.

Seagate Constellation ES.3 Hard Drive
ST3000NM0023 (S2MMMC)

133. To access the magnetic material structure, the top of each [redacted] Product was removed so that a view of the drive interior is visible and accessible, as shown below for Sample S0GPPC.

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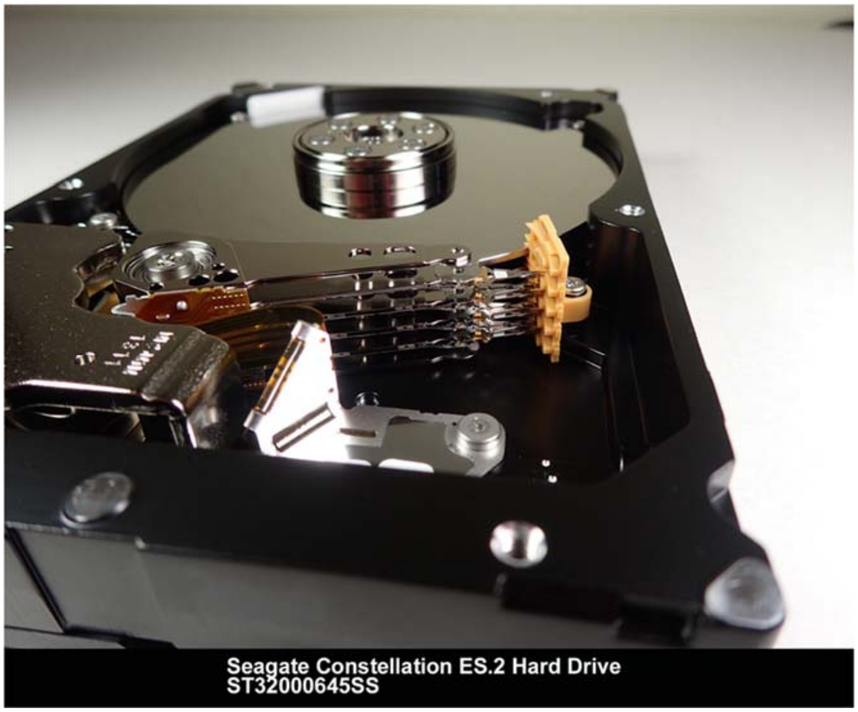
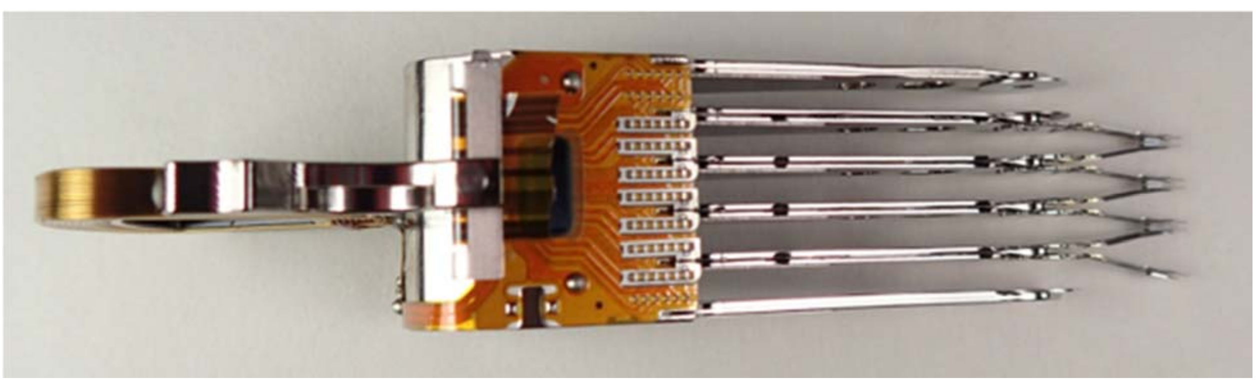


134. After the top of each [redacted] Product was taken off, the actuator arm with head gimbal assemblies was removed, and is shown in the first image below from Sample S0GPPC. A zoomed in image of the HGAs in Sample S0GPPC is also shown in the second image below.



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135. To view the magnetic material structure in the write head, a FEI 200 TEM FIB using a gallium focused ion beam was used to take an image of the heads at the tip of an HGA. Specifically, an image of the slider containing the heads in sample S0GPPC is shown below.

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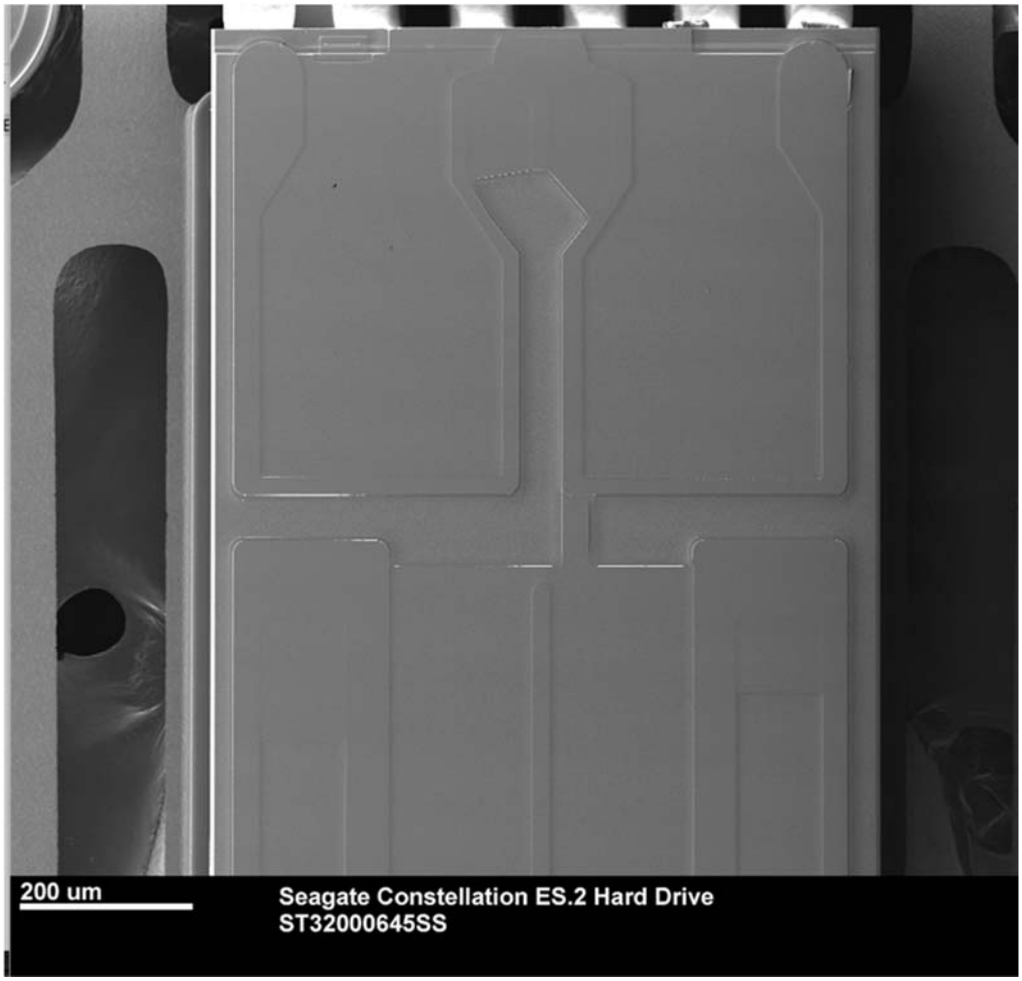

136. A region of the slider was then identified as containing the write head and, as shown below for Sample S0GPPC, a section of this region was coated with platinum to create a region that may be removed as cross-section from the write head showing the magnetic material structure therein.

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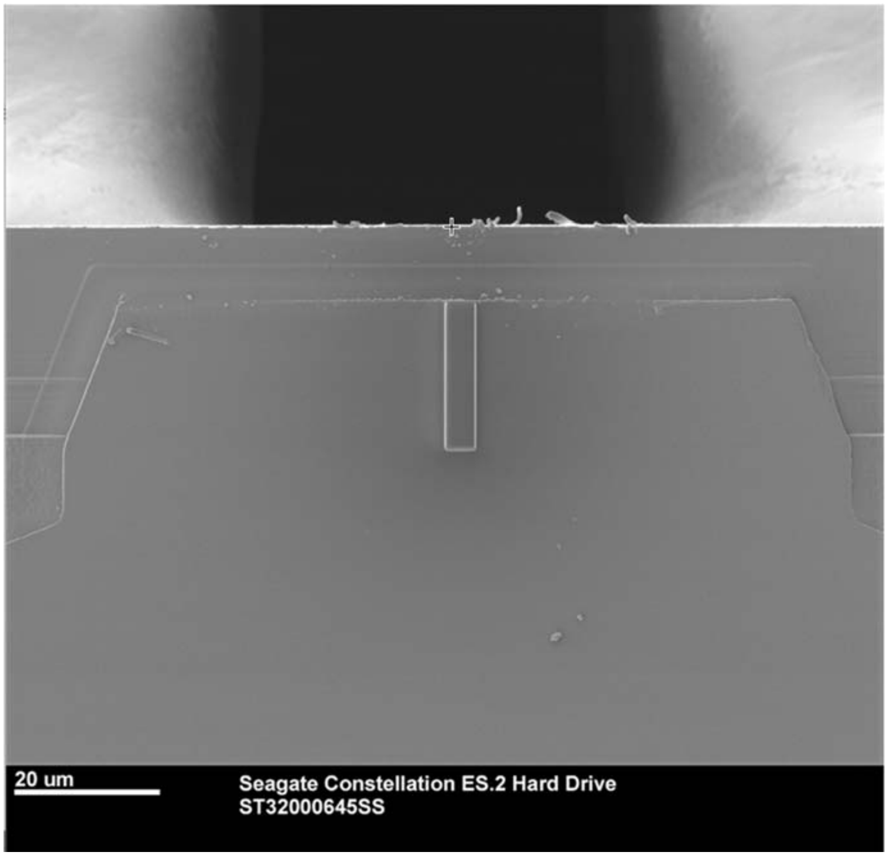

137. After the platinum was deposited, material was removed from the slider by a gallium FIB such that the cross-section sample could be lifted out. Specifically, the gallium FIB was used to perform an in-situ lift out. *See, e.g.*, Giannuzzi, L.A. Kempshall, B.W., et al., INTRODUCTION TO FOCUSED ION BEAMS: INSTRUMENTATION, THEORY, TECHNIQUES AND PRACTICE, "FIB Lift-out Specimen Preparation Techniques: Ex-Situ and In-Situ Methods," Lucille A. Giannuzzi, eds., (2005); Kempshall, B.W. and L.A. Giannuzzi, "In-Situ Lift-Out FIB Specimen Preparation for TEM of Magnetic Materials," *Microsc. Microanal.*, 8 (Suppl. 2), 2002, 590-91; Giannuzzi, Lucille A., Brian W. Kempshall, et al., "FIB Lift-Out for Defect Analysis," *Microelectronic Failure Analysis Desk Reference 2002 Supplement*, 29-35; Kempshall, B.W., et al., "A microstructural observation of near-failure thermal barrier coating: a study by photostimulated luminescence spectroscopy and transmission electron microscopy," *Thin Solid*

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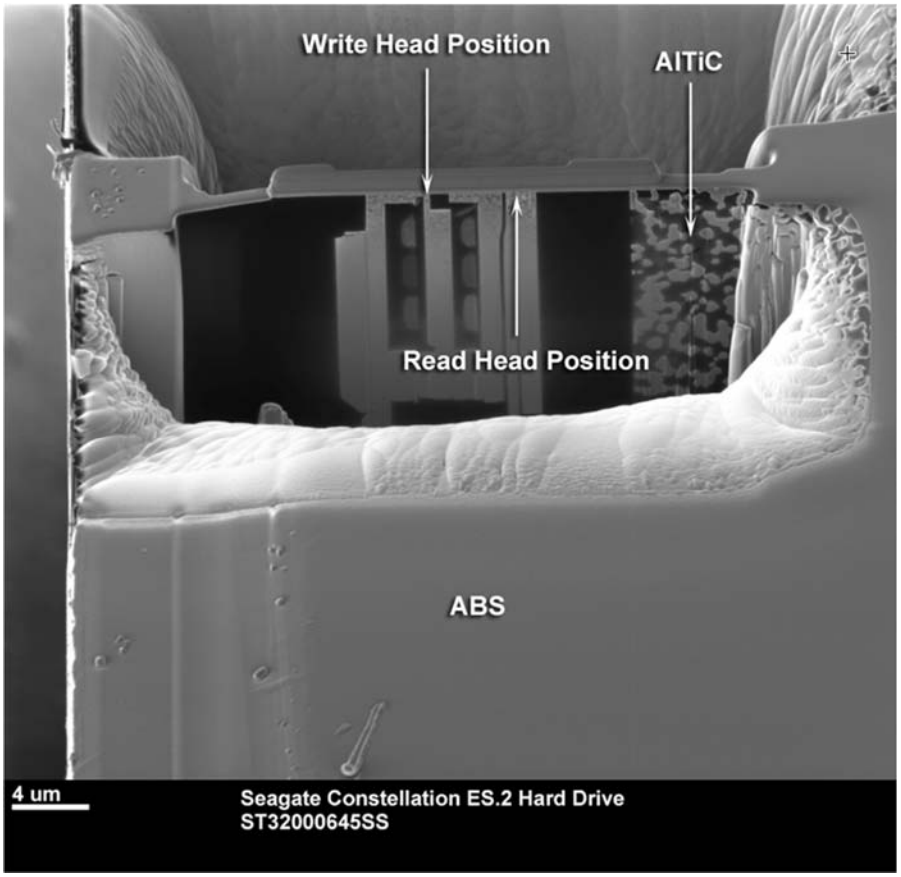
Films, 466 (2004) 128-136. In the image below from Sample S0GPPC, the AlTiC wafer substrate is visible, as well as the write head. At this level of magnification, the individual layers of material in the write head are not easily observable.



138. The cross-section sample removed by the gallium FIB was then lifted out of the slider by the micromanipulator probe, here a Omniprobe 100, as shown below in an image from Sample S0GPPC. After the cross-section from each [redacted] Product was prepared using the gallium FIB, it was mounted on a TEM grid using the Omniprobe 100 inside the FEI FIB device. The use of the gallium FIB does not have an impact on the samples prepared using this tool (specifically, the FEI FIB) at least because the analyses subsequently conducted are not sensitive to gallium concentration and because the surface imaged here is ultimately removed in the final

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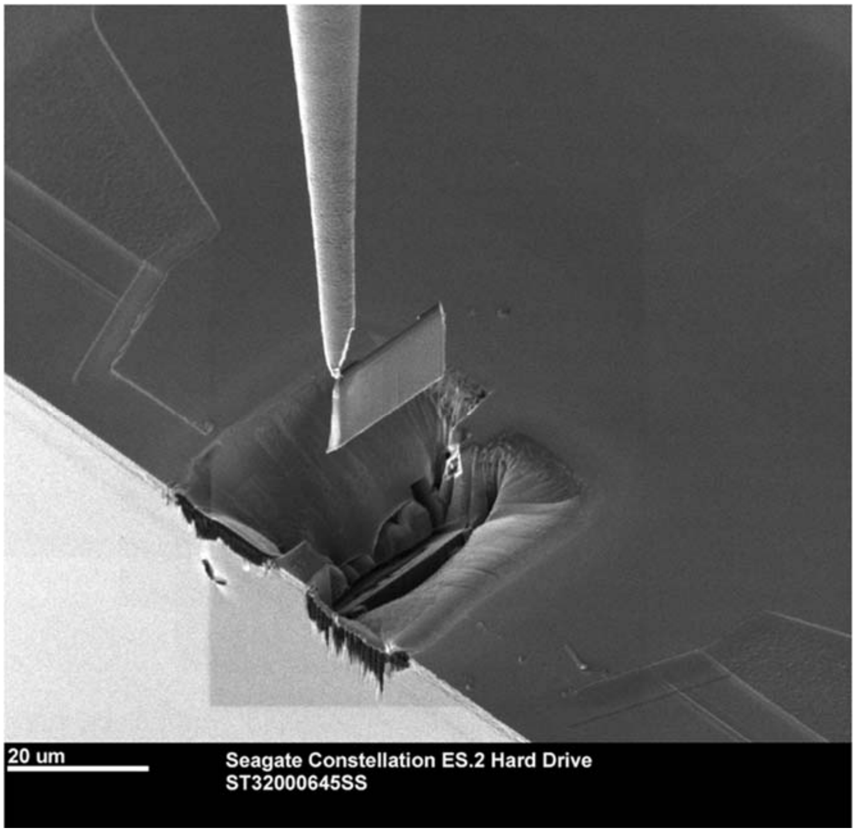
thinning of the sample performed after the sample is placed on the TEM grid, discussed further in the next paragraph.



139. SEM imaging in the Zeiss Crossbeam 1540 XB was used to obtain a high-resolution image from the cross-sections from both [redacted] Product samples, S0GPPC and S2MMMC. The Zeiss Crossbeam instrument was also used to further thin the sample for enhanced electron transparency. It is possible to observe several features of the slider. For instance, in the backscatter 1 kV image below, the coils and the main write pole (including iron cobalt layers extending to the ABS) are shown on the left side of the image below for sample S0GPPC. The read head is also visible on the right side of the image below. Further to the left and right of the heads, the lower and upper shields are visible.

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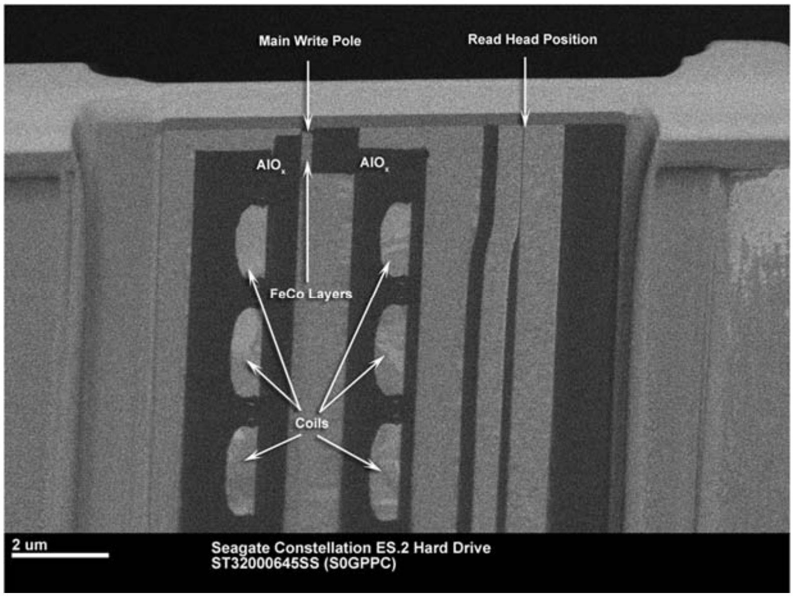
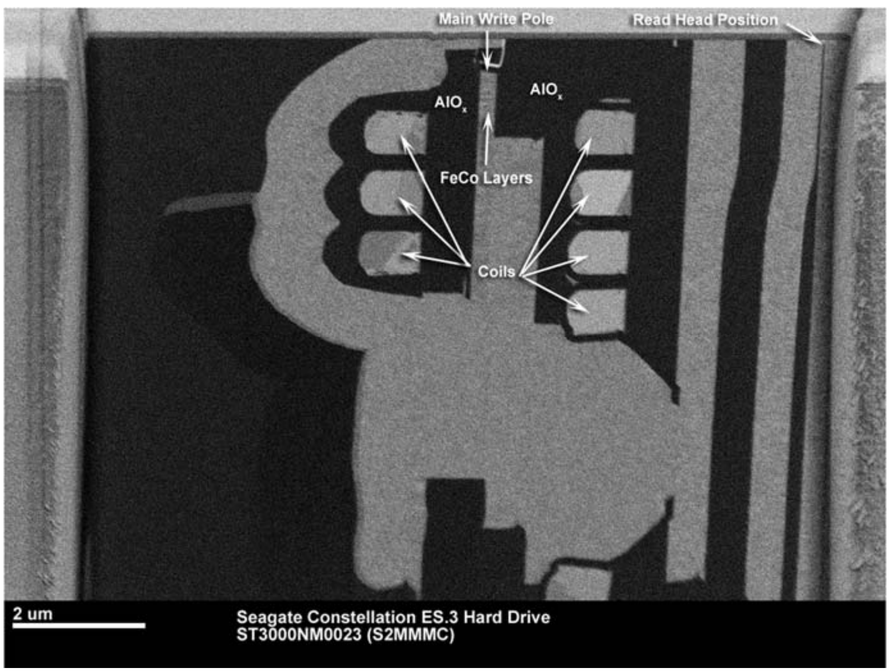


140. A similar cross-section image is shown for sample S2MMMC below.



141. Analyzing the S0GPPC sample and the S2MMMC sample in a TEM Tecnai F30 operated at 300 kV in brightfield mode, one can observe the magnetic material structure meeting the limitations of claim 1 of the ‘988 patent is in the write head. This magnetic material structure can be observed using TEM to inspect the FIB-prepared cross-section sample at higher

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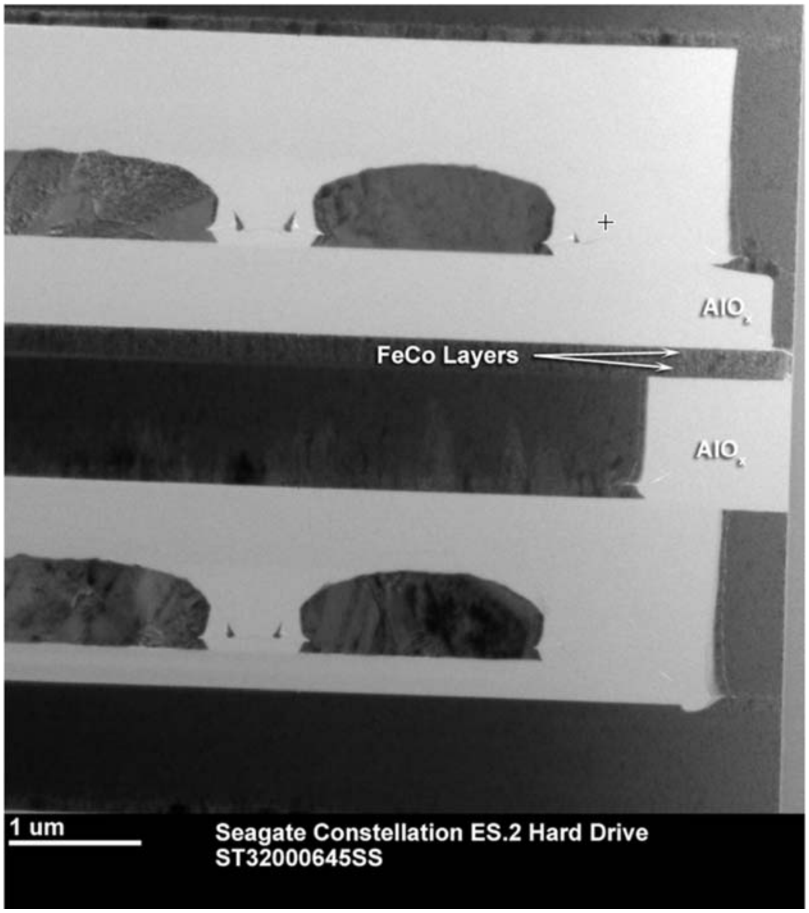
magnification. The first image below shows Sample S0GPPC, and the second image below shows Sample S2MMMC.



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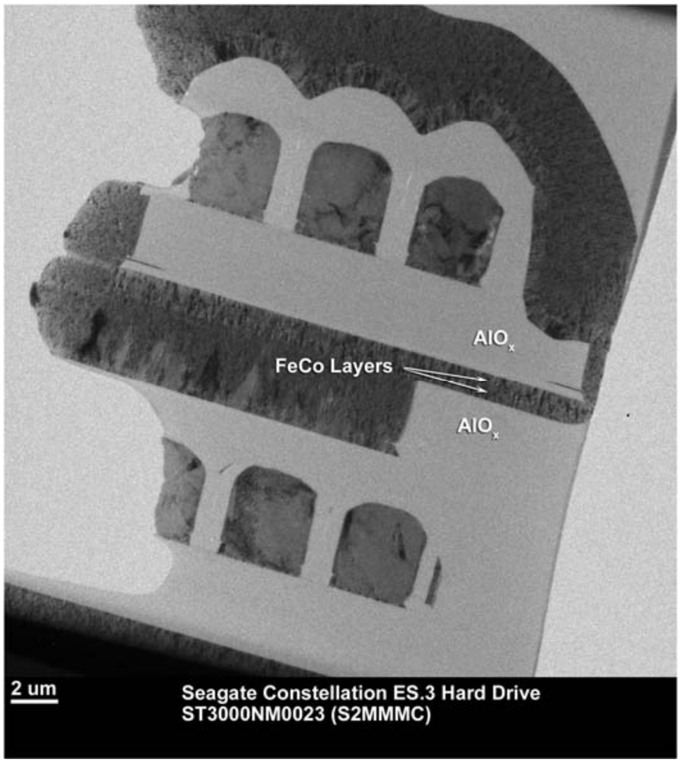

142. A higher magnification image of the write pole materials is provided in the first image below for Sample S0GPPC, and in the second image below for Sample S2MMMC.

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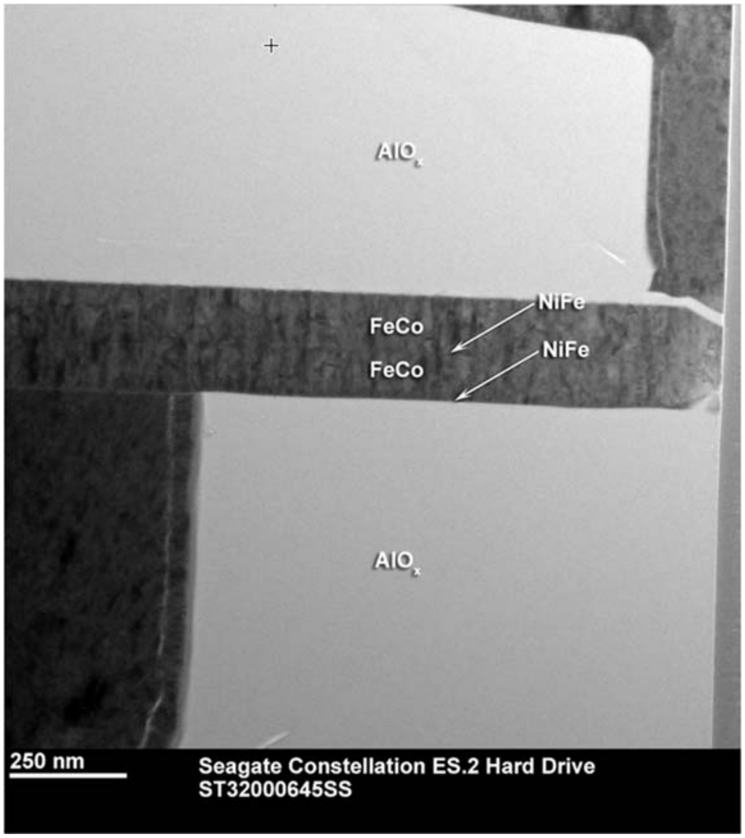

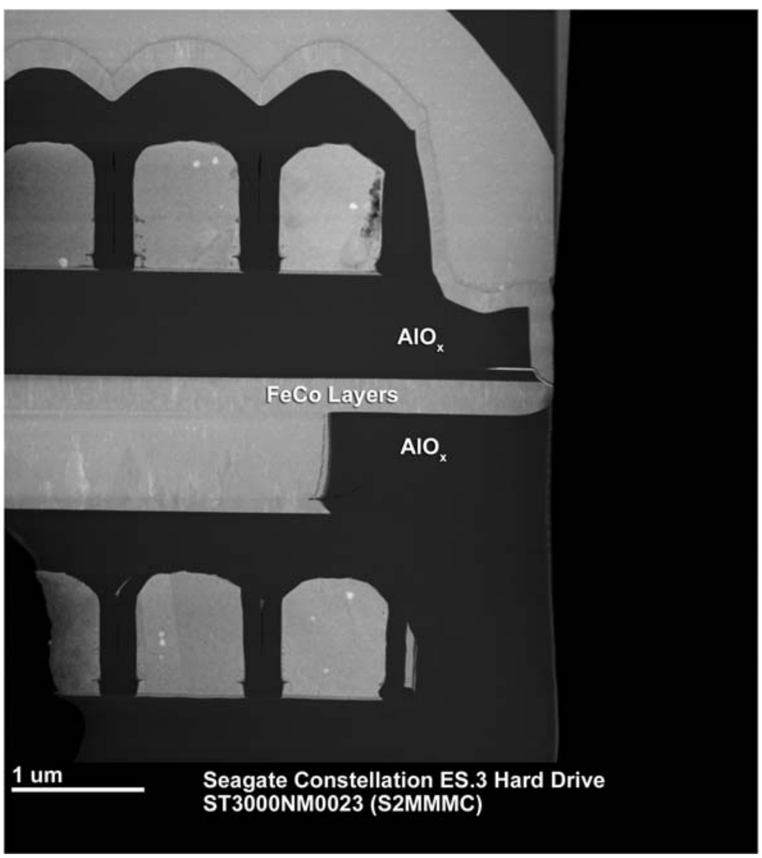

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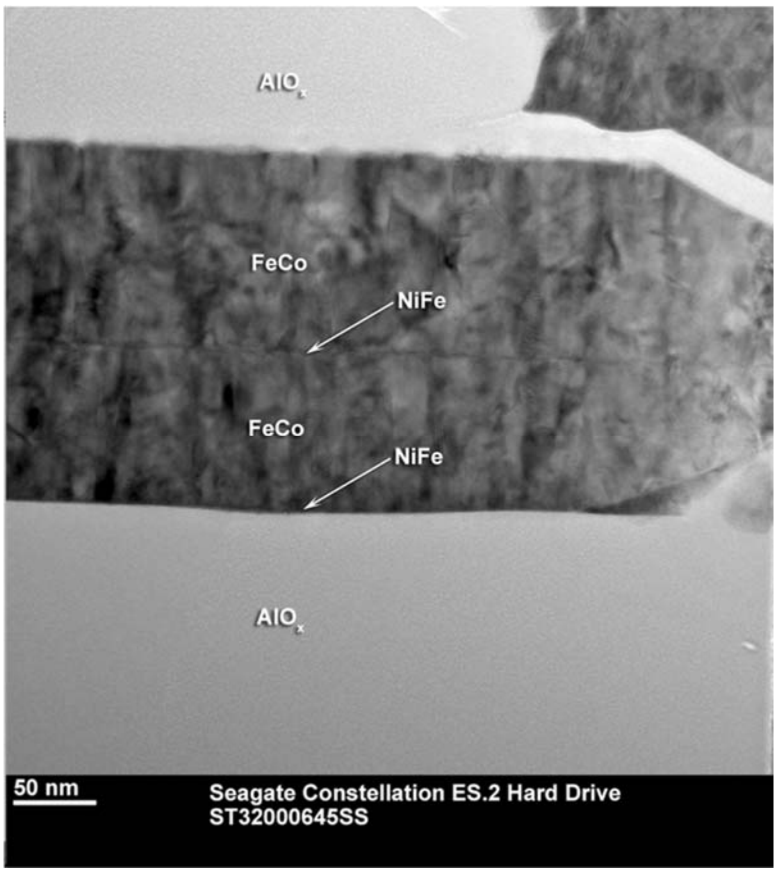
143. Using even greater magnification via TEM imaging of the cross-section samples from [redacted] Products in the Tecnai tool, I can observe the layer structure of the FeCo layers on the NiFe template layers. Note that the AlTiC substrate of the magnetic material structure of claim 1, is not observable in many images illustrating the material layers in the write pole due to the high level of magnification necessary to show on the FeCo and NiFe layers. The image below shows Sample S0GPPC.



144. In the claimed magnetic material structure, both the FeCo and the NiFe layers are magnetic. The growth direction is of the layers shown in the images above is from the bottom of the image to the top.

145. I understand that further TEM imaging at high resolution was performed on the cross-section of the write head prepared samples S0GPPC and S2MMMC, as described in Dr.

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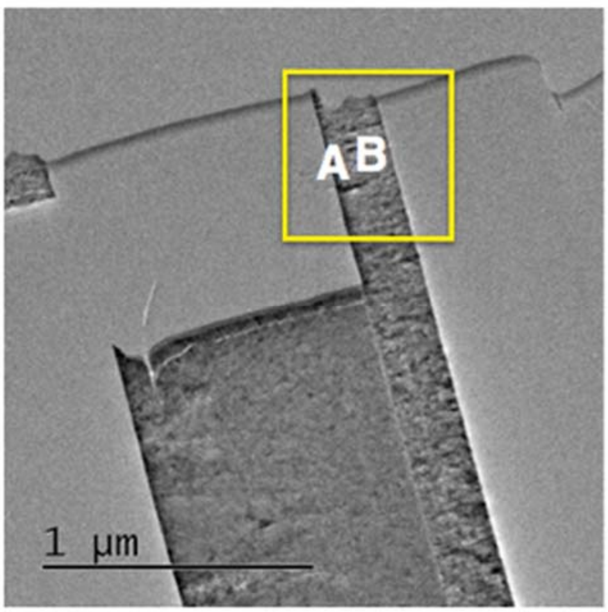
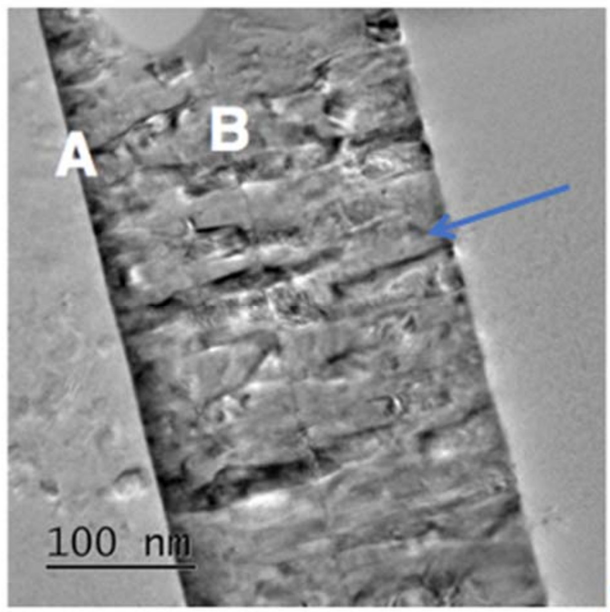
Clark's report. *See* Plaintiff Lambeth Magnetic Structures, LLC's Initial Expert Report of Dr. William Alan Thomas Clark ("Clark Report") at Sections E.2. and F.1.a.2. These additional TEM images of a cross-section of [redacted] Products illustrate the layers in the write head that are part of the claimed magnetic material structure, including magnetic material layers of FeCo and NiFe. *See id*. at Sections F.1.a.2. and F.1.b.2. In the TEM images below reproduced from Dr. Clark's Report, the magnetic layers are observable and growth direction annotated. The upper images depict sample S0GPPC and the lower images depict sample S2MMMC.





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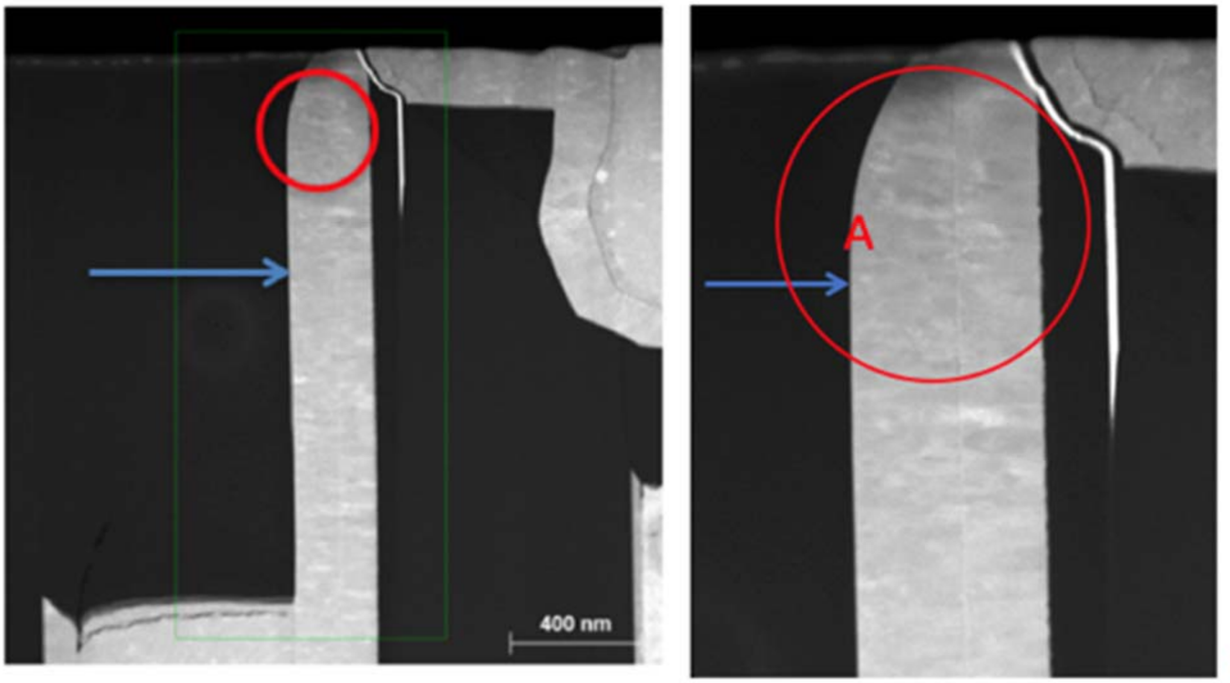
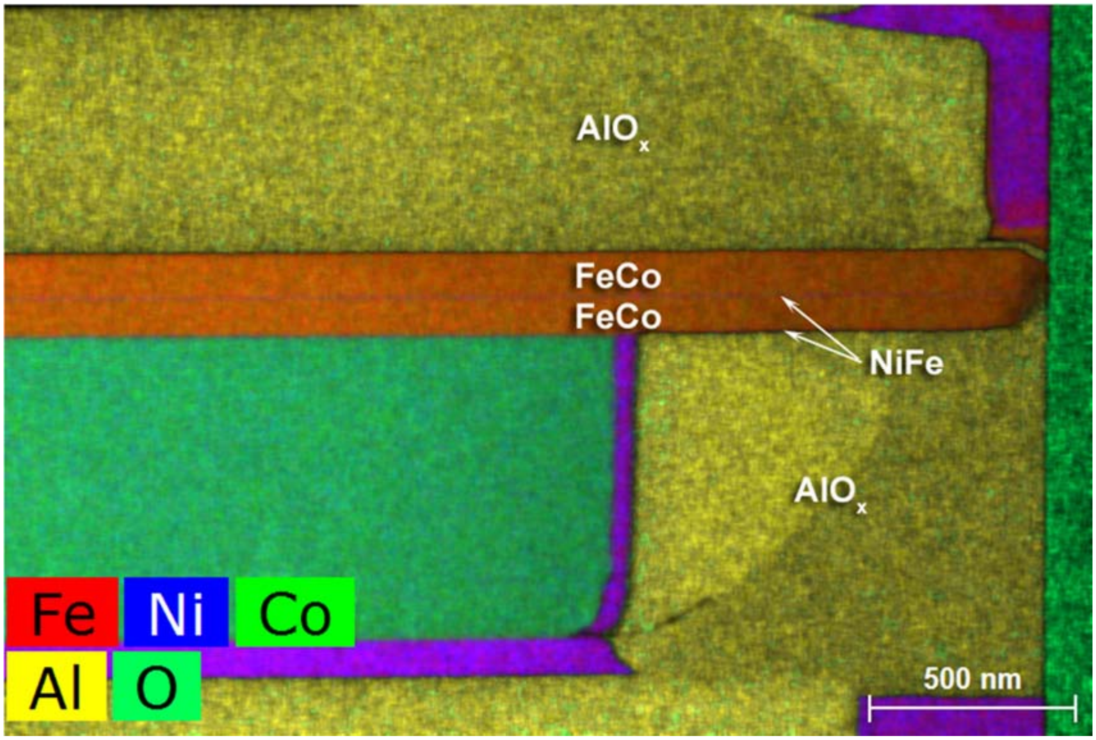
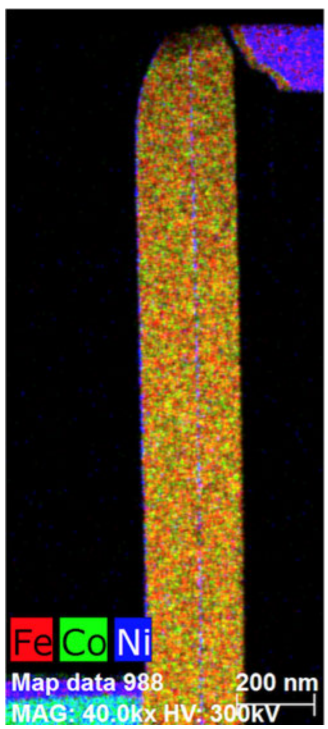


146. I further understand that composition of the magnetic material layers in the write head for [redacted] Products was confirmed by using energy dispersive x-ray spectroscopy ("EDS"), as described in Dr. Clark's report. *See* Clark Report at Sections E.3, F.1.a.1, F.1.b.1. From the EDS imaging of sample S0GPPC and sample S2MMMC shown below, magnetic layers of the write head that are part of the claimed magnetic material structure can be observed, specifically FeCo and NiFe layers, as shown below. Here, the growth direction for the NiFe and FeCo layers is from the bottom of the image towards the top in the upper image of sample S0GPPC, and the growth direction is from left to right in the lower image of sample S2MMMC.





147. EDS performed on the sample at higher magnification, shown below, reveals the NiFe layers more clearly. The image below depicts sample S0GPPC (growth direction from top to bottom).

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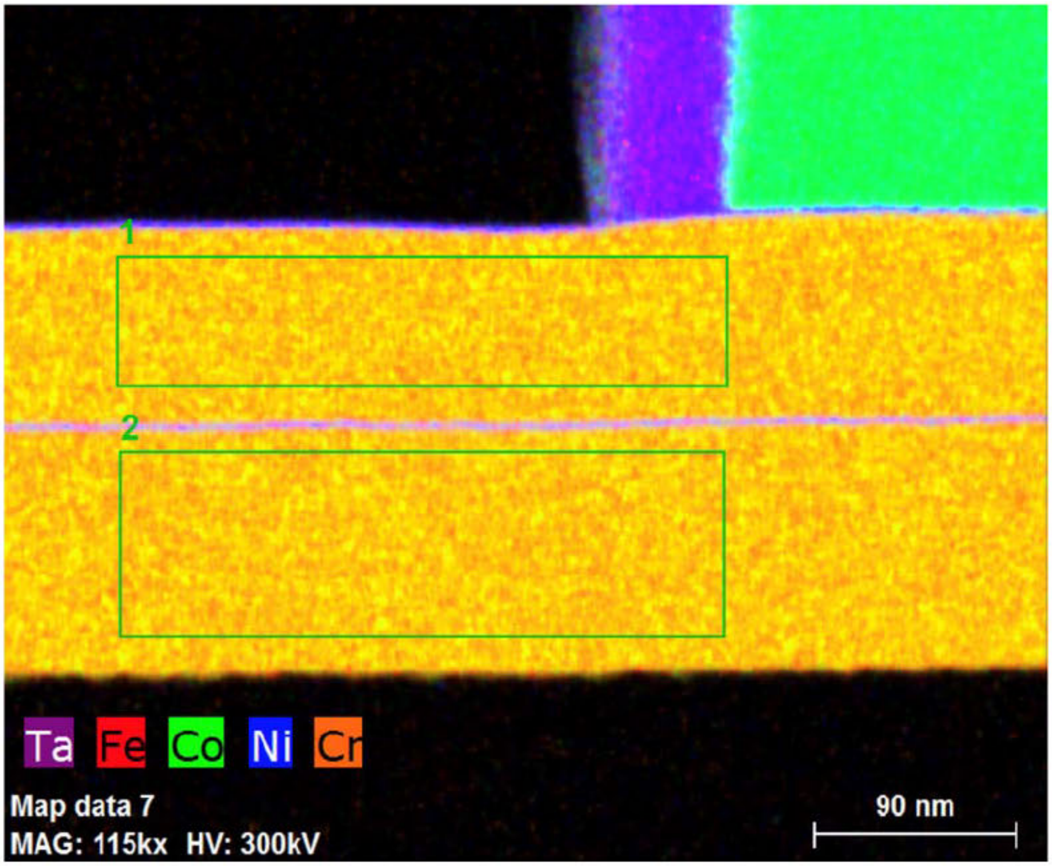

148. [redacted]

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[redacted]

149. In consideration of all of the evidence described above, it is my opinion that the [redacted] Products include a magnetic material structure including, at least, an AlTiC wafer material, and at least one layer of NiFe material and at least one layer of FeCo material within the write pole.

150. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet the preamble, to the extent it is limiting.

151. Thus, it is my opinion that, to the extent the preamble to claim 1 is limiting, it is met by the [redacted] Products.

b) Element (a) of Claim 1, "a substrate," is met by the [redacted] Products

152. Element (a) of claim 1 of the '988 patent provides "a substrate."

153. [redacted]

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[redacted]

154. I also confirmed the presence of the AlTiC wafer substrate below the write pole in the [redacted] Products by analyzing cross-sections from representative [redacted] Products, specifically sample S0GPPC and sample S2MMMC, via imaging in a FEI 200 TEM FIB gallium focused ion beam ("FIB") system during lift out of a cross-section sample. The process of preparing the cross-section sample is discussed in detail above in Section VI.1.a. In the image below, the AlTiC wafer substrate is visible on the right side of the image for sample S0GPPC and on the left side of the image for sample S2MMMC, and the material layers comprising the head, including the write pole, deposited on top of the AlTiC wafer substrate are visible to the left for S0GPPC and to the right for S2MMMC. The first image below depicts sample S0GPPC, and the second image depicts sample S2MMMC.

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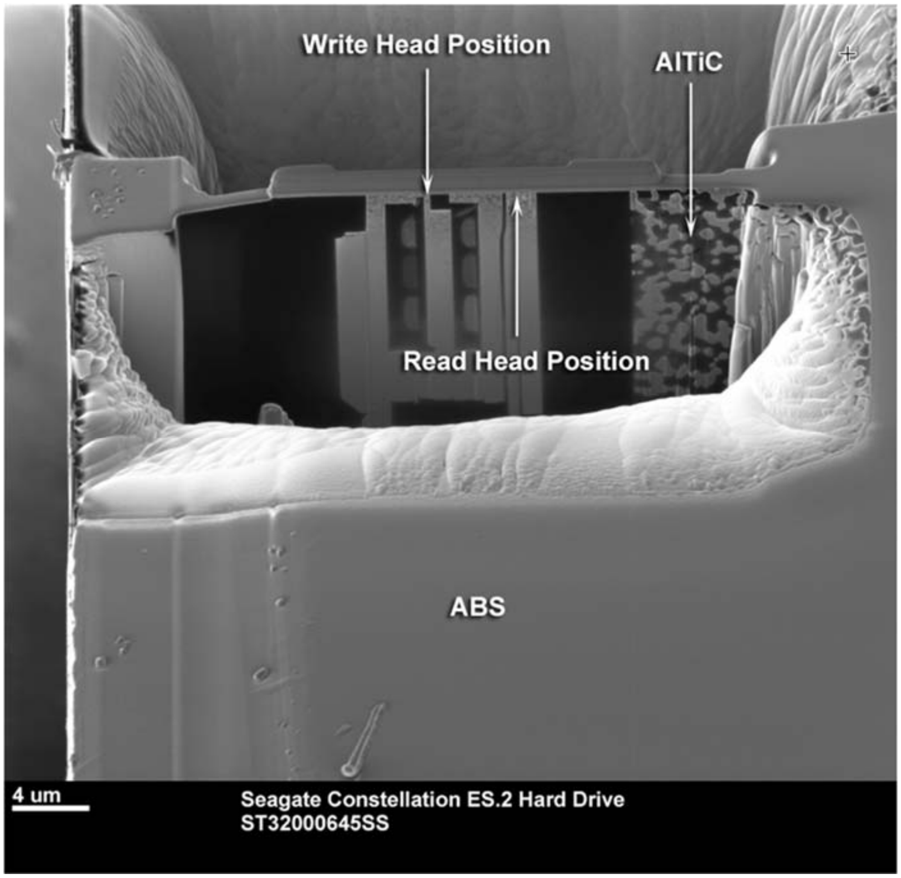

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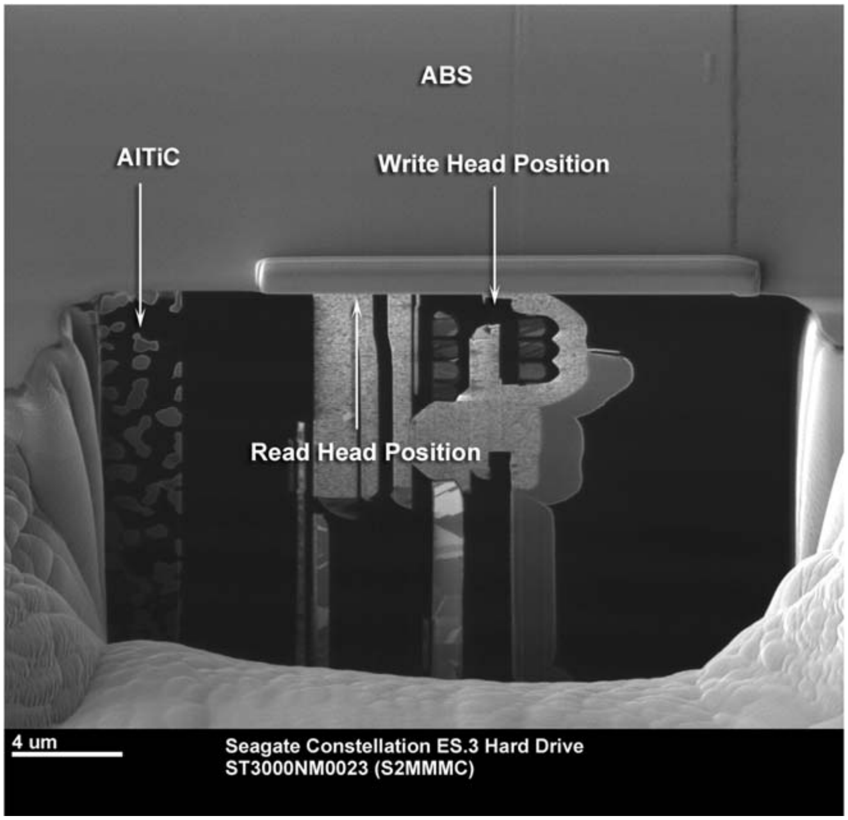

155. [redacted]

156. [redacted]

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157. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

158. Therefore, for at least the reasons described above, the [redacted] Products include a substrate, which is an AlTiC wafer. Thus, it is my opinion that element (a) of claim 1 of the '988 patent is met by the [redacted] Products.

c) Element (b) of Claim 1, "at least one bcc-d layer which is magnetic," is met by the [redacted] Products

159. Element (b) of claim 1 of the '988 patent provides "at least one bcc-d layer which is magnetic."

160. [redacted]

161. [redacted]

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[redacted]

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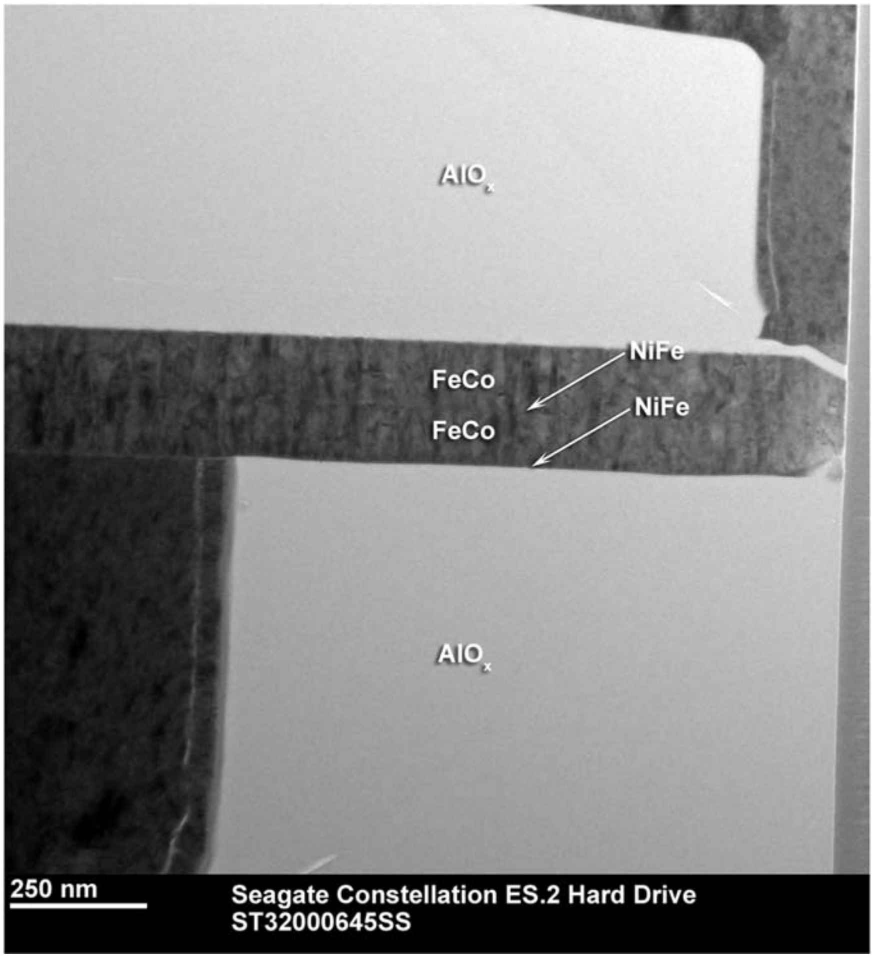

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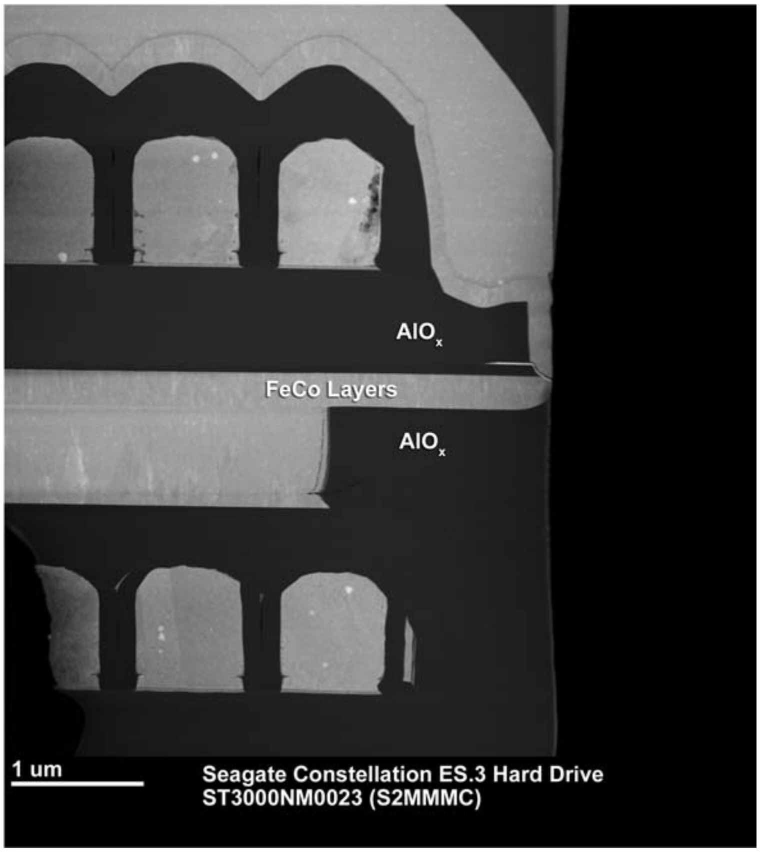

162. I also confirmed the presence of the two FeCo layers in the [redacted] write pole, including the lower layer, in the EDS analysis shown below. I understand that these image were taken in a TEM on the same cross-sections of sample S0GPPC and sample S2MMMC, both representative [redacted] Products, discussed at Section VI.1.a. above and confirms the composition of the layers shown, including the lower FeCo layer that is the magnetic bcc layer on which I am basing my infringement opinion with respect to claim 1 of the '988 patent. *See* Clark Report at Sections F.1.a.1. and F.1.b.1. The first image below depicts sample S0GPPC, and the second image depicts sample S2MMMC.

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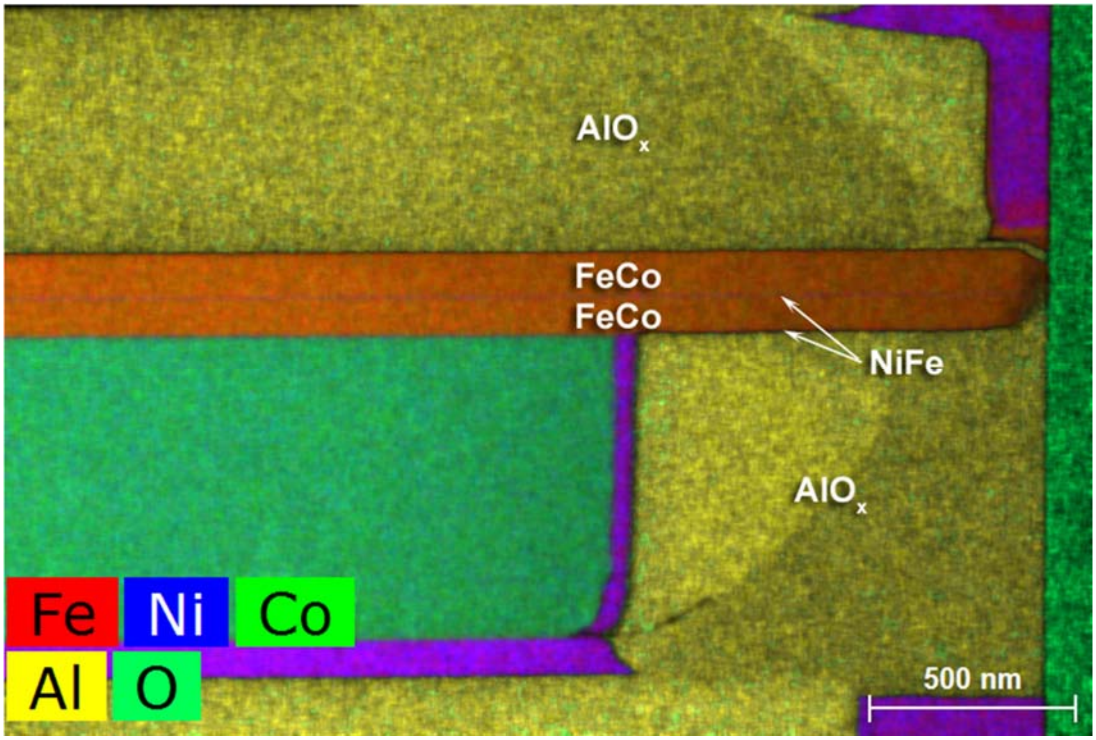

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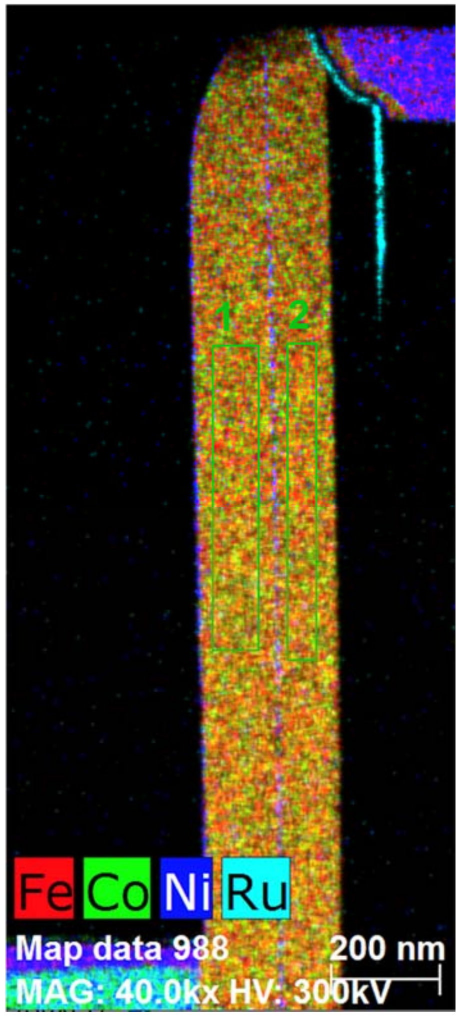

163. I understand that analysis of a series of FFTs performed on a high resolution TEM image in the area of the lower FeCo layer of representative [redacted] Products, sample S0GPPC and sample S2MMMC, in the area where lattice fringes are observed shows that the lower FeCo layer has a bcc crystal structure. *See* Clark Report at Sections E.2.i., F.1.a.3., and F.1.b.3. Dr. Clark created and analyzed a series of FFTs from the interfaces between NiFe and FeCo layers across the sample.

164. I understand that Dr. Clark's analysis of FFTs led him to conclude that the lower FeCo layer in both representative [redacted] Products, sample S0GPPC and sample S2MMMC, has a bcc crystal structure. *See* Clark Report at Sections F.1.a.3. and F.1.b.3..

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165. Plan view samples from heads from representative [redacted] Product samples S0GPPC and S2MMMC were further prepared via the in-situ lift out technique. *See, e.g.*, Giannuzzi, L.A. Kempshall, B.W., et al., INTRODUCTION TO FOCUSED ION BEAMS: INSTRUMENTATION, THEORY, TECHNIQUES AND PRACTICE, "FIB Lift-out Specimen Preparation Techniques: Ex-Situ and In-Situ Methods," Lucille A. Giannuzzi, eds. (2005); Kempshall, B.W. and L.A. Giannuzzi, "In-Situ Lift-Out FIB Specimen Preparation for TEM of Magnetic Materials," *Microsc. Microanal.*, 8 (Suppl. 2), 2002, 590-91; Giannuzzi, Lucille A., Brian W. Kempshall, et al., "FIB Lift-Out for Defect Analysis," *Microelectronic Failure Analysis Desk Reference 2002 Supplement*, 29-35; Kempshall, B.W., et al., "A microstructural observation of near-failure thermal barrier coating: a study by photostimulated luminescence spectroscopy and transmission electron microscopy," *Thin Solid Films*, 466 (2004) 128-136. The plan view sample was prepared and imaged in a FEI 200 TEM FIB gallium focused ion beam ("FIB") system as shown in the images below to provide a sample comprising the lower FeCo layer of the write pole material in sample S0GPPC. A plan view sample from a head from representative [redacted] Product Sample S2MMMC was prepared by the same method as illustrated and described below for Sample S0GPPC.

166. In the image below, a platinum coating was deposited on a region of the slider so that it could be removed to form a plan view sample taken from the write head to present the lower FeCo layer of the write pole material in sample S0GPPC. The cross-section preparation and imaging discussed above facilitated the determination of the correct location for removing the plan view sample.

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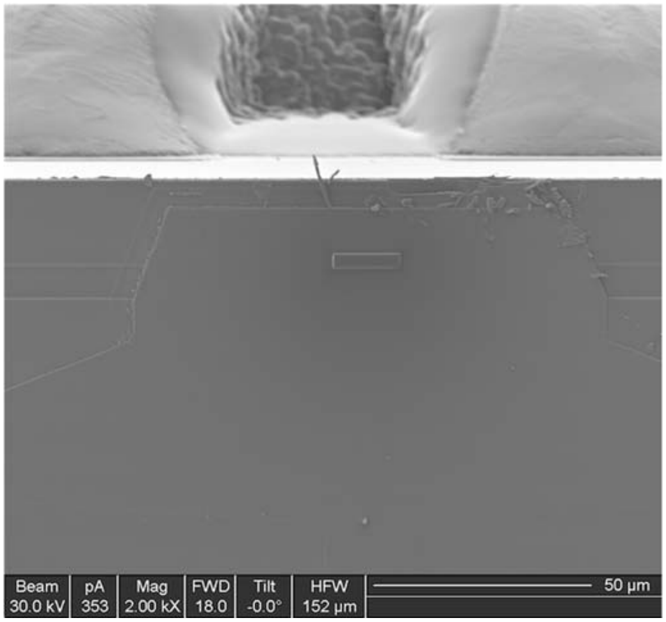
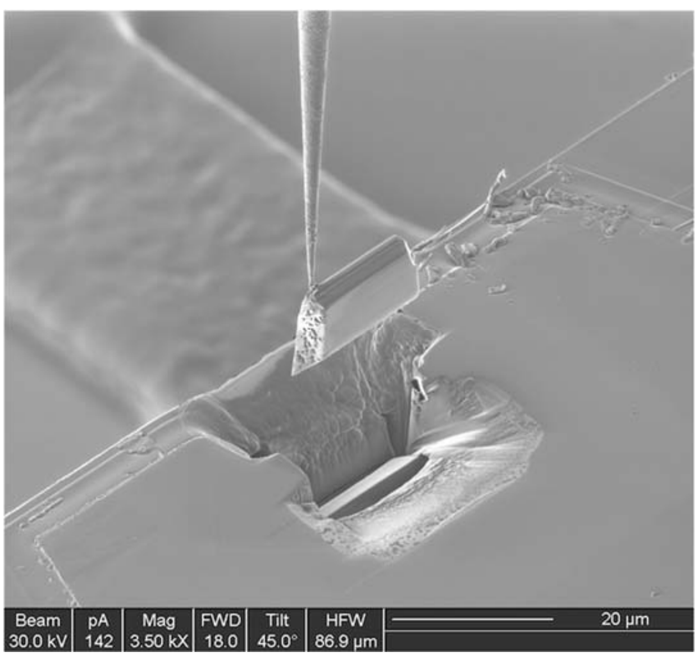


167. In the image below, the tungsten micromanipulator probe, an Omniprobe 100, is attached to the sample during the lift out process as the sample is extracted from the bulk slider. Between the prior image and the image below, the gallium FIB was used to trench out the material in front, behind, and undercut to release the sample from the slider via the in-situ lift out technique discussed above.



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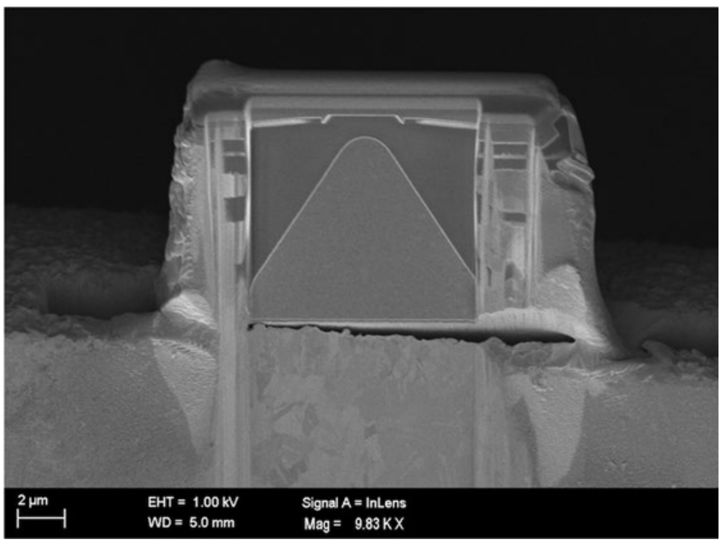
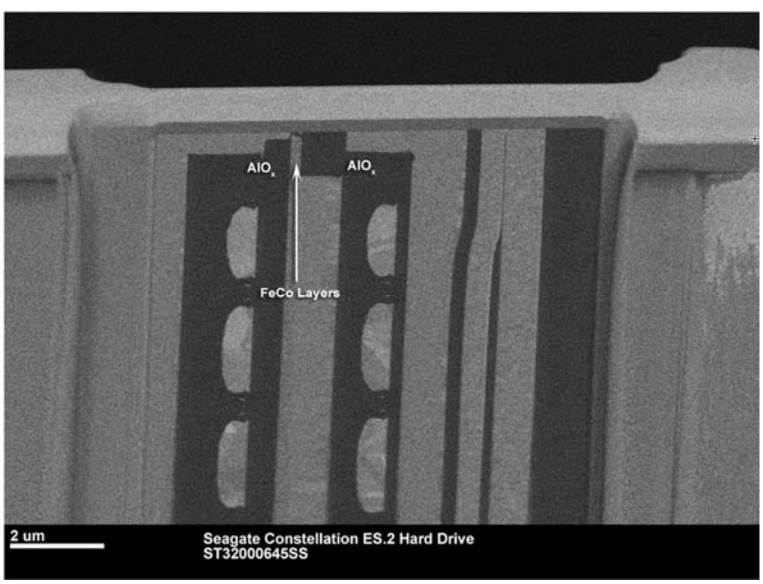
168. Once lifted out of the slider, the sample was removed from the tungsten probe and attached to a TEM grid using the ion beam for CVD platinum deposition. The image below was taken by the Zeiss Crossbeam during the process of milling away material to isolate the layer of interest. For reference, at the stage shown in the image below, the layer of interest has not yet reached the surface. With reference to the cross-section image shown in the second image below, milling shown in the first image below is proceeding from the right to left side of the cross-section in the second image below.





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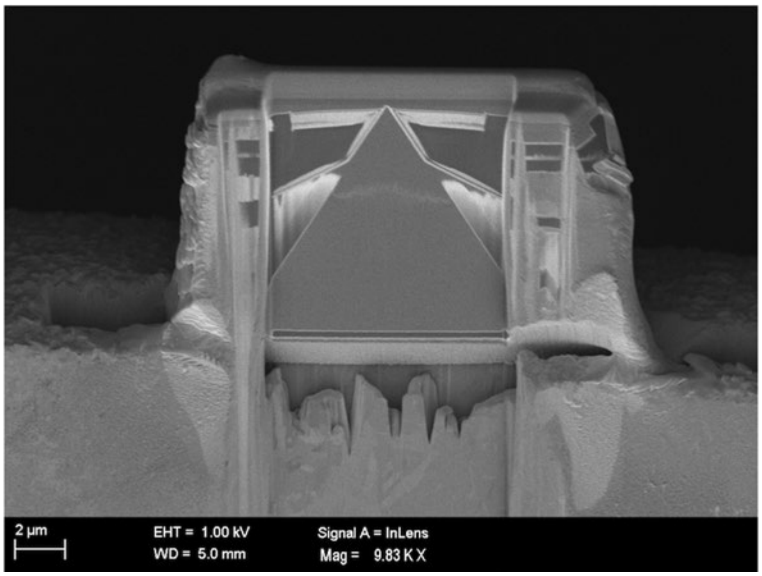
169. In the image below, the milling process in the Zeiss Crossbeam instrument is approaching the layer of interest that will be isolated. As can be observed in the comparison to the cross section image above, the lower FeCo layer, which is the layer of interest for this plan view sample, clearly reaches the ABS. Thus, the milling is getting closer to isolating the layer of interest.



170. In the image below, the remaining portion of the lower NiFe layer has been removed fully exposing the layer of interest. Milling also occurs from the other side, but due to the geometry of the SEM and Crossbeam tool, there are no images from that side.

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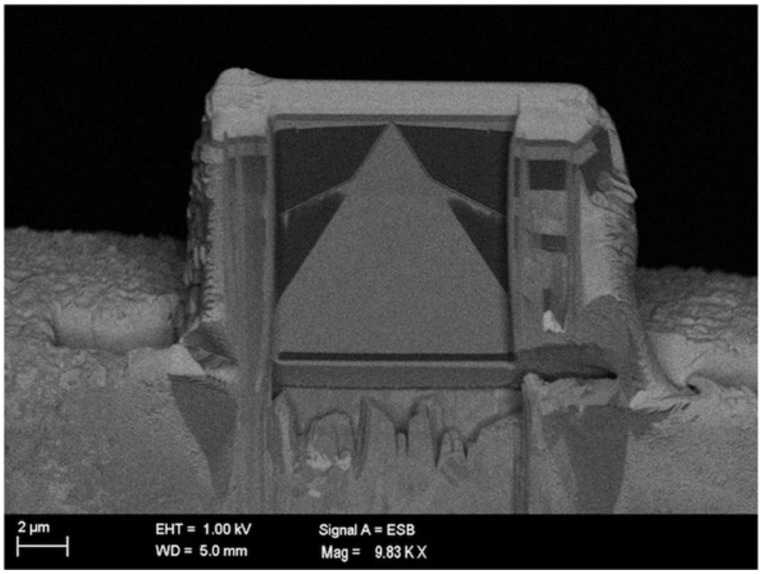
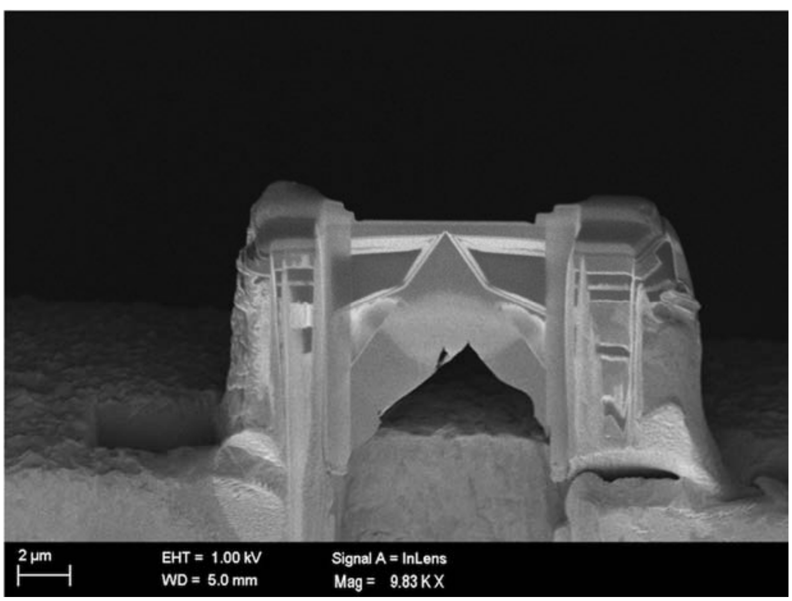


171. In the image below, the sample of the lower FeCo layer has been milled down to adequate transparency for further analysis. There is a small hole observable in the lower FeCo layer, which was created by the process of milling from the other side of the sample to ensure that only the lower FeCo layer is present in this foil for analysis by TEM techniques, as discussed herein and in Dr. Clark's report.



172. Additionally, I understand that analysis of microbeam diffraction data collected from plan view samples from S0GPPC and S2MMMC, which are representative [redacted] Products,

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confirms that the lower FeCo layer in the [redacted] Products have a bcc crystal structure and a (110) crystal texture. *See* Clark Report at Sections E.2.d., F.1.a.4., and F.1.b.4.

173. [redacted]

174. [redacted]

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[redacted]

175. [redacted]

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176. [redacted].

177. In sum, [redacted]

178. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

179. Therefore, for at least the reasons described above, the [redacted] Products comprise at least one bcc-d layer which is magnetic. Thus, it is my opinion that element (b) of claim 1 of the '988 patent is met by the [redacted] Products.

d) Element (c) of Claim 1, "forming a uniaxial symmetry broken structure," is met by the [redacted] Products

180. Element (c) of claim 1 of the '988 patent provides "forming a uniaxial symmetry broken structure."

181. Element (c) is literally met by the [redacted] Products. Specifically, the [redacted] Products all contain a lower layer of FeCo material in the write pole that includes multiple polycrystalline grains of (110) textured bcc FeCo. The grains of (110) bcc FeCo in the lower layer of FeCo material in the write pole of the [redacted] Products are oriented relative to the (111) hexagonal template provided by the NiFe template layer directly beneath them such that the lower FeCo layer consists of variants from the six variant Kurdjumov-Sachs system. As discussed further below and in Dr. Clark's report, the lower layer of FeCo material in the [redacted] Products' write poles has unequal amounts of the bcc variants in the Kurdjumov-Sachs six

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variant system and, accordingly, is symmetry broken according to the Court's construction of the term "symmetry broken." Furthermore, as discussed further below and in Dr. Clark's report, the result of the symmetry breaking in the lower layer of FeCo in the [redacted] Products' write poles is uniaxial anisotropy in the measured region of that material layer. Specifically, the unequal amounts of variants in the six variant system observed by dark field image analysis at different angles as a sample was rotated by 180 degrees from a physical axis were measured and the resulting anisotropy energy density function was calculated. As discussed in further detail below, it is my opinion that the lower layer of FeCo in the [redacted] Products is uniaxial because the anisotropy energy density function I calculated solely due to the measured broken symmetry in representative samples of the [redacted] Products has a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis.

182. The lattice parameters of the bcc FeCo magnetic layers and fcc NiFe hexagonal template layers used by Seagate for the [redacted] head are reasonably well known (Bozorth at 104, 192; Singh et al, J. Mag. & Mag. Mat., v 324, p 999, 2012) and from these the ratios of fcc to bcc nearest neighbor distances can be calculated and are within the range of 1.04 to 1.01. For this range, the six variant Kurdjumov-Sachs orientation relationship is favored over the 3 variant Nishiyama-Wasserman orientations, and this six variant system is what is experimentally observed for the [redacted] Product samples, S0GPPC and S2MMMC.

183. I understand that microbeam diffraction analysis of representative samples of the [redacted] Products shows that the lower layer of FeCo in the write pole contains multiple (110) bcc crystalline grains that are members of the Kurdjumov-Sachs six variant system. *See* Clark Report at Sections E.2.d., F.1.a.4., and F.1.b.4. I understand that Dr. Clark performed microbeam diffraction analysis on the area of plan view samples from S0GPPC and S2MMMC

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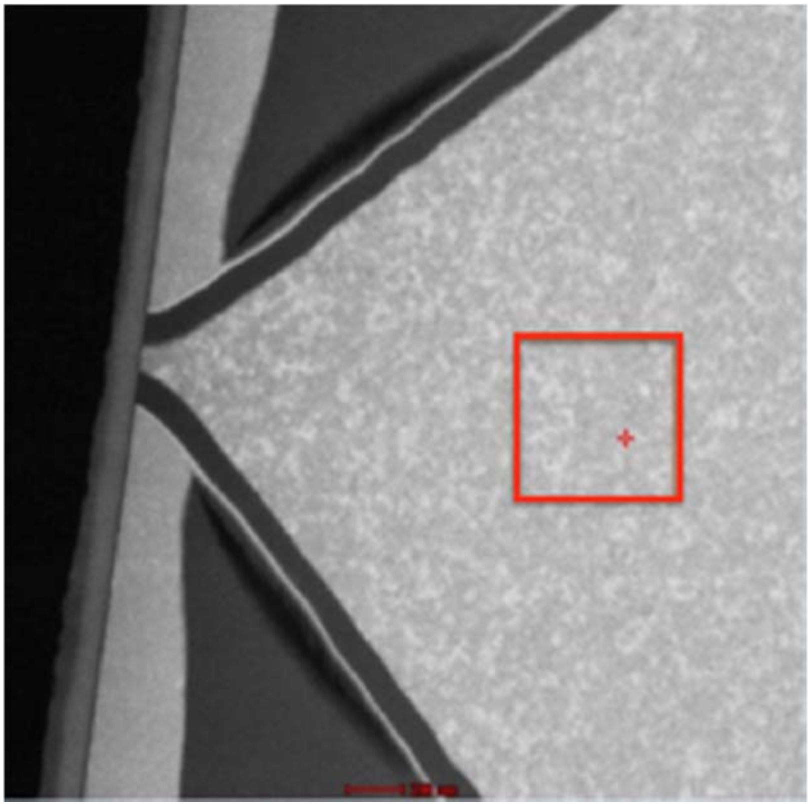
as indicated by the red annotation on the TEM images below, which are reproduced from Dr. Clark's report. *See id*. The first image below depicts sample S0GPPC, and the second image depicts sample S2MMMC.



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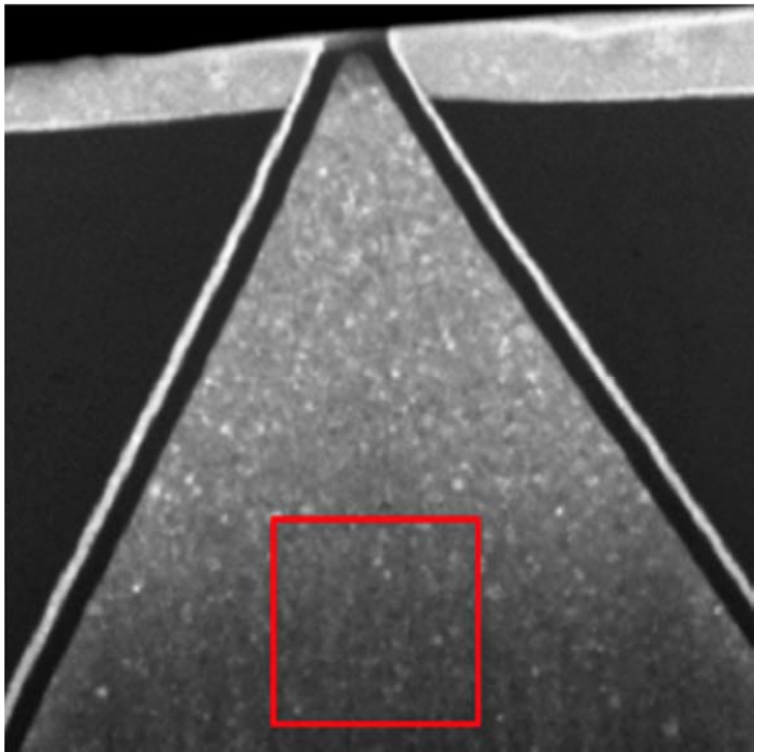

184. I further understand that there are unequal amounts of variants from the Kurdjumov-Sachs six-variant system in the lower layer of FeCo in sample S0GPPC based on high resolution cross-sectional imaging. *See id.* at Section F.1.a.3. Dr. Clark used FFTs to analyze a cross-section sample from sample S0GPPC to confirm that the FeCo grains in the lower layer of FeCo and the lower layer of NiFe have an epitaxial $(111)_{NiFe}||(110)_{FeCo}$ orientation relationship with the in-plane directions $\langle 111\rangle_{bcc}||\langle 110\rangle_{fcc}$, which confirms that the FeCo grains are composed of variants from the Kurdjumov-Sachs six-variant system. *See id.* As discussed above, sample S0GPPC is representative of the [redacted] Products (*see* Section VI.1.a.) and, accordingly, I conclude that each of the [redacted] Products has a lower layer of FeCo that forms a symmetry broken

185. Similarly, I understand that there are unequal amounts of variants from the Kurdjumov-Sachs six-variant system in the lower layer of FeCo in sample S2MMMC based on high resolution cross-sectional imaging. *See id.* at Section F.1.b.3. Dr. Clark used FFTs to

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analyze a cross-section sample from sample S2MMMC to confirm that the FeCo grains in the lower layer of FeCo and the lower layer of NiFe have an epitaxial $(111)_{NiFe}||(110)_{FeCo}$ orientation relationship with the in-plane directions $<111>_{bcc}||<110>_{fcc}$, which confirms that the FeCo grains are composed of variants from the Kurdjumov-Sachs six-variant system. *See id*. As discussed above, sample S2MMMC is representative of the [redacted] Products (*see* Section VI.1.a.) and, accordingly, this supports my conclusion that each of the [redacted] Products has a lower layer of FeCo that forms a symmetry broken structure.

186. I further understand from Dr. Clark's report that the in-plane dimensions of the bcc crystals of the FeCo layer are comparable to the in-plane dimensions of the crystals in the NiFe hexagonal template layer with which they have a six-variant Kurdjumov-Sachs relationship. *See* Clark Report at Sections F.1.a.3 and F.1.b.3; *see also id*. at Sections F.1.a.5. and F.1.b.5. Accordingly, it is unlikely for there to be more than two such bcc variants on a single template crystal, and it is extremely unlikely to have all six variants on a single template crystal. *See id*. It is even more unlikely to have equal amounts of all six variants on a single template crystal. *See id*. Accordingly, this structure literally meets the Court's construction of "symmetry broken" as it is a structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system.

187. I also understand that dark field image analysis of samples S0GPPC and S2MMMC show symmetry breaking in the lower layer of FeCo in the write pole. *See* Clark Report at Sections E.2.f., F.1.a.5., and F.1.b.5. I understand that Dr. Clark performed a dark field imaging analysis on the area of a plan view sample from samples S0GPPC and S2MMMC as indicated by the red annotation on the TEM image below, which is reproduced from Dr. Clark's report. *See id*.

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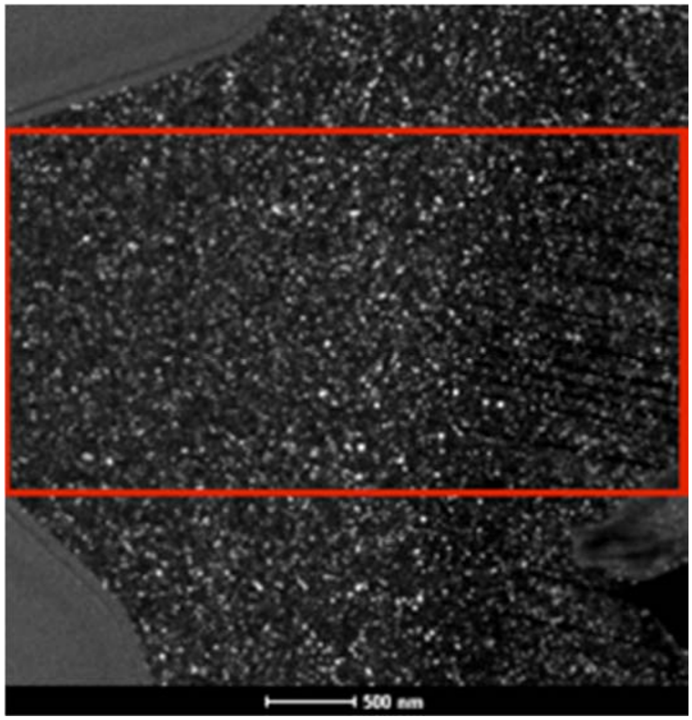

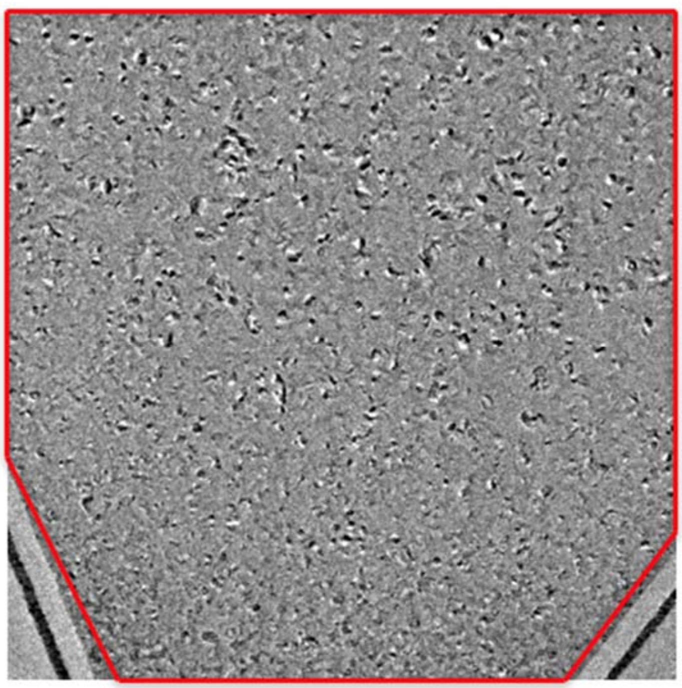

188. I further understand that this dark field analysis determined the relative area fractions of crystallites having aligned <100> directions as a function of the measurement angle in the plane at 10 degree intervals from a physical axis for samples S0GPPC and S2MMMC. *See*

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Clark Report at Sections F.1.a.5. and F.1.b.5. I understand that this dark field imaging analysis provides information on the fraction of crystallites with their easy axes substantially aligned toward each measured orientation and, consequently, shows the presence of unequal amounts of variants in the Kurdjumov-Sachs six-variant system because a greater amount of bcc-d crystallites are composed of variants with their easy axis aligned substantially perpendicular to the long axis of the write head (parallel to the ABS) than in other directions. *See id*. As discussed above, sample S0GPPC is representative of the [redacted] Products (*see* Section VI.1.a.) and, accordingly, dark field analysis supports my conclusion that each of the [redacted] Products has a lower layer of FeCo that forms a symmetry broken structure. In addition, sample S2MMMC is representative of the [redacted] Products (*see* Section VI.1.a.) and, accordingly, dark field analysis of sample S2MMMC also supports my conclusion that each of the [redacted] Products has a lower layer of FeCo that forms a symmetry broken structure.

189. Using the results of Dr. Clark's dark field imaging analysis [redacted] Product samples S0GPPC and S2MMMC, I performed further analysis to determine that the lower FeCo layer in the write pole of [redacted] Products has an anisotropy energy density function with only a single maximum and a single minimum as the magnetization is rotated by 180 degrees from a physical axis due solely to the anisotropy resulting from the presence of unequal amounts of the bcc-d variants of a six variant system in the lower FeCo layer. That is, it is my opinion that the lower FeCo layer in the [redacted] Products is uniaxial as a result of the structure therein being symmetry broken, in accordance with the Court's construction of claim 1 of the '988 patent.

190. My analysis to determine that the lower FeCo layer is uniaxial as a result of the structure therein being symmetry broken utilized Dr. Clark's dark field imaging analysis. I understand that Dr. Clark's dark field imaging analysis of [redacted] Product samples S0GPPC and

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S2MMMC, determined the relative area fractions of crystallites having aligned <100> directions in the film plane as a function of the measurement angle in the plane. *See* Clark Report at Sections F.1.a.5. and F.1.b.5. Dr. Clark made such measurements at 10 degree intervals in rotation of 180 degrees or more from a physical axis. Dr. Clark's raw data, as it was provided to me, is presented in Appendix F. The symmetry of the bcc crystal structure is such that crystals having a <100> direction in the plane aligned at 80 degrees will necessarily also have a <100> direction in the plane at 80 + 180 = 260 degrees, and this is the case for all data provided by Dr. Clark. Accordingly, I used this crystal symmetry to extend the range of data to 360 degrees (a full circle), allowing the variation in area percentage with angle to be evident. When more than one experimental value for the area fraction was available at orientations 180 degrees apart, these values were averaged to be consistent with crystal symmetry and reduce the experimental variation of the data. The data area fraction data was then normalized over the range of 0 to 360 degrees to provide a sum total area of 100%. This in-plane orientation data of the (110) textured bcc FeCo crystallites had a systematic sinusoidal variation in area fraction as a function of angle from a physical axis. In addition to the sinusoidal variation, small random deviations from the sinusoidal variation were present. To identify the magnitude of the sinusoidal variation the data for each sample was modeled by the equation:

$$Area\ Fraction = A(\sin(\Theta + \Delta))^2 + B(\cos(\Theta + \Delta))^2$$

The values of A, B and □ were chosen to minimize the sum of the squared differences between the equation and experimental values at each angle, □, where the normalized experimental values were available (least squared fitting). The figure below is a plot of the normalized experimental data (as points) along with a solid curve calculated with the equation above for the SOGPPC sample.

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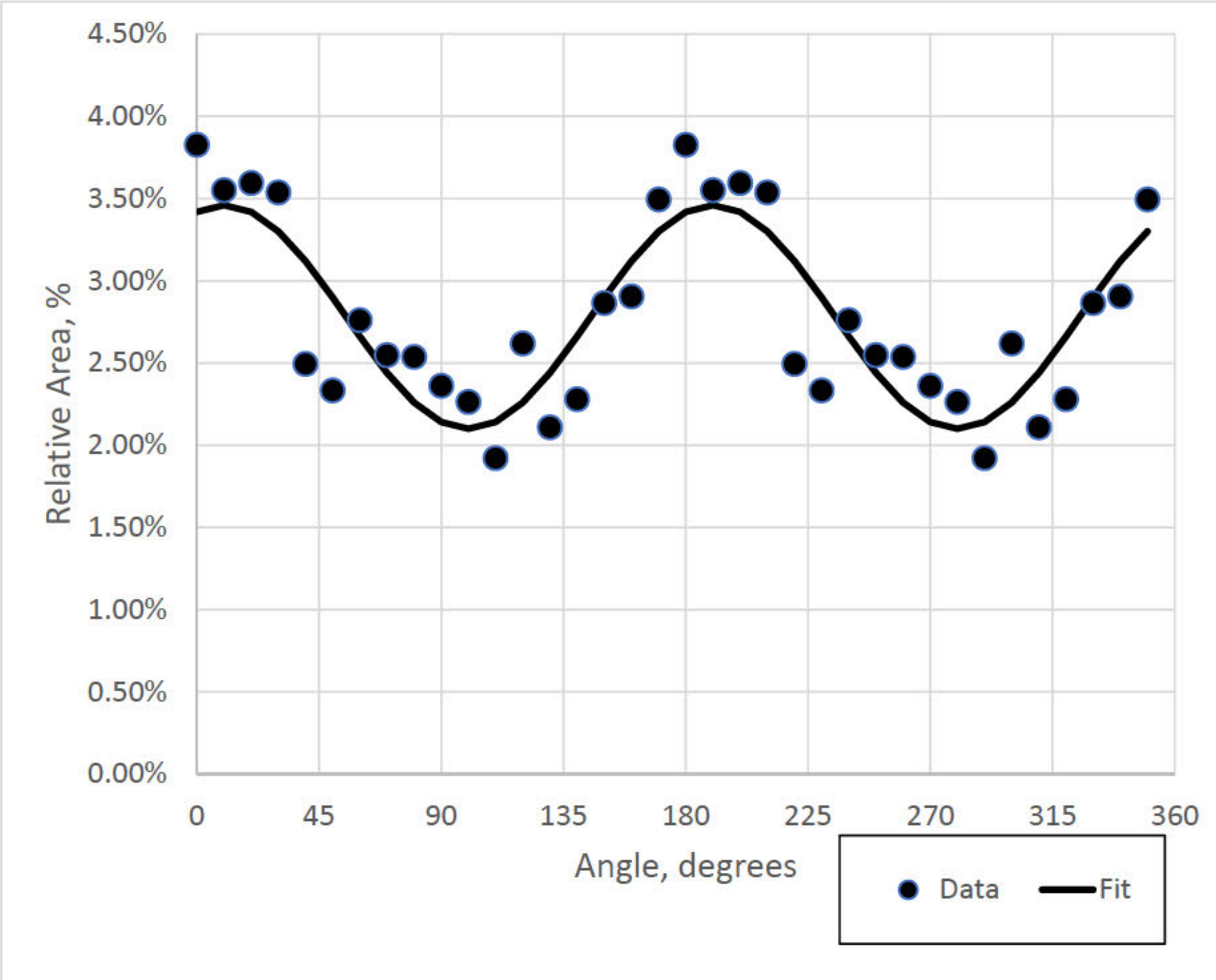

The area fraction for the (110) bcc, six-variant crystallites is not independent of direction, rather it shows a pronounced variation as a function of angle. Accordingly, not all variants are equally present and the S0GPPC sample has broken symmetry. For this sample, the orientation at zero degrees was chosen to be parallel to the ABS, and peak in area fraction near 0/360 and 180 degrees is understood as being parallel to the ABS.

191. The figure below is a plot of the normalized experimental data (as points) along with a solid line calculated with the equation above for the S2MMMC sample. *See* Appendix G.

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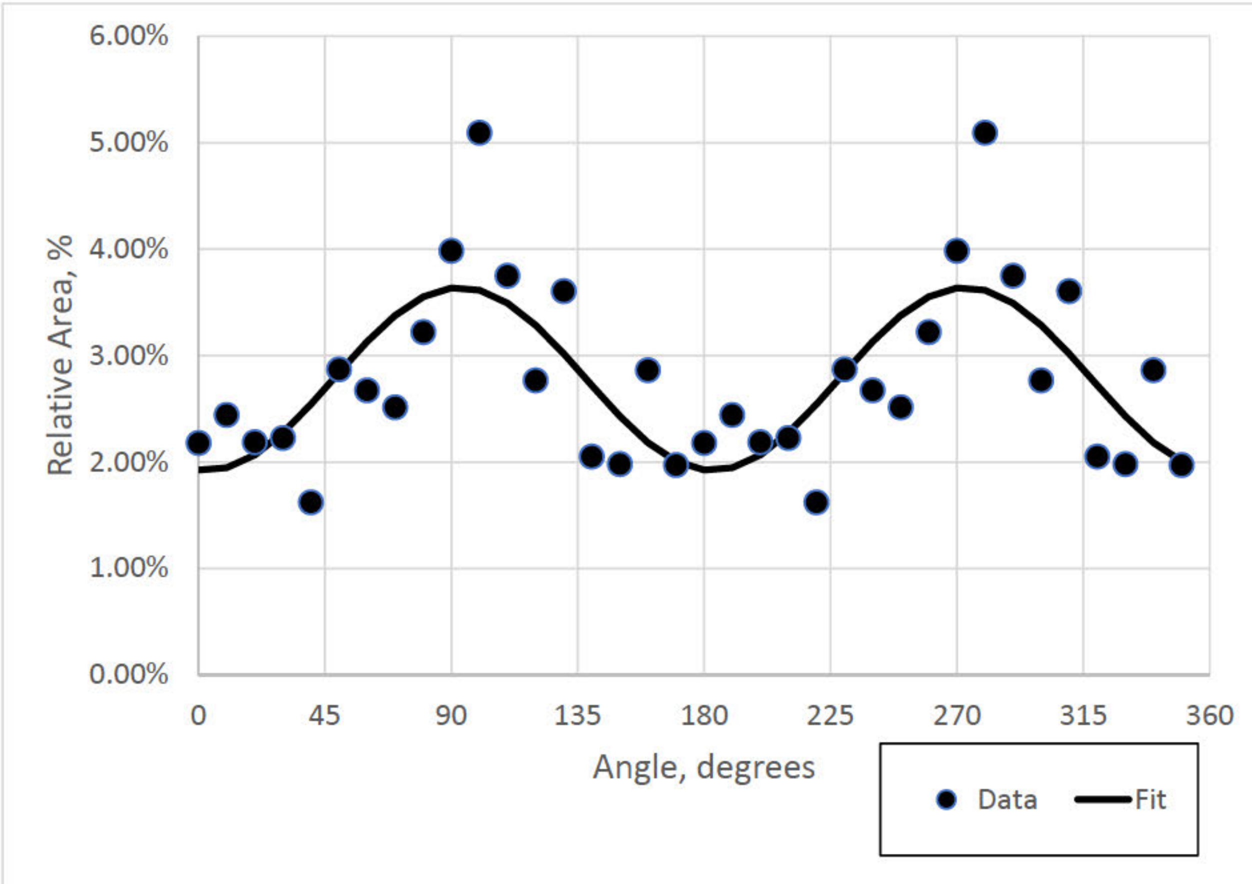

The area fraction for the (110) bcc, six-variant crystallites is not independent of direction, rather it shows a pronounced variation as a function of angle. Accordingly, not all variants are equally present and the S2MMMC sample has broken symmetry. For this sample, the orientation at zero degrees was chosen to be perpendicular to the ABS, and peak in area fraction near 90 and 270 degrees is understood as being parallel to the ABS.

192. It is well known in the literature that all bcc-d crystals have a smooth anisotropy energy density function in the (110) plane. Indeed, the anisotropy energy density function for bcc-d crystals in the (110) plane is set forth in Chikazumi and referenced in the '988 patent. *See* Soshin Chikazumi, PHYSICS OF FERROMAGNETISM (1997) ("Chikazumi") at 259-266; '988 patent at col. 11, ll. 30-58). Specifically, the equation is:

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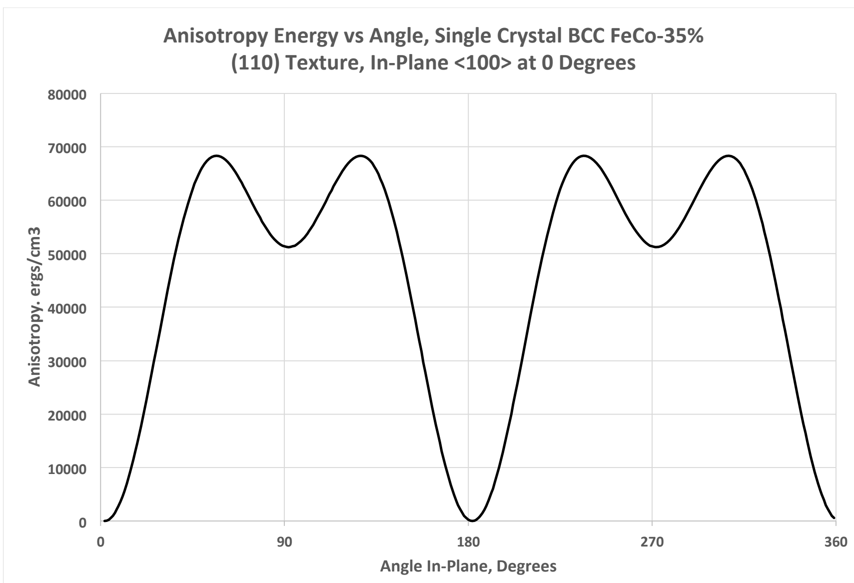
$$E_{110}(\Theta) = K_1\{(^1/_4)sin^4(\Theta) + \sin^2(0)\cos^2(\Theta)\} + K_2\{(^1/_4)\sin^4(\Theta)\cos^2(\Theta)\}$$

$$+ \text{ higher } K \text{ terms}$$

193. To illustrate that this anisotropy energy density function for the (110) plane of bcc-d crystals is a smooth function, I have plotted the function below for a single bcc crystal having a (110) texture and an in-plane <100> direction at zero degrees. (Note that for this chart, from Appendix D, as for the [redacted] Products, K_2 and higher terms are negligible.)



194. In the '988 patent, Dr. Lambeth calculated the anisotropy energy density function associated with combinations of variants in a bcc-d magnetic layer on a single crystal template. *See, e.g.*, '988 patent at 18:46-23:15. Here, the [redacted] Products have polycrystalline template layers beneath the FeCo layers that are the bcc-d magnetic layers. Accordingly, to determine the overall anisotropy energy density due to the symmetry breaking evidenced in the lower FeCo

layer in the [redacted] Products it is necessary to calculate the anisotropy energy density as an average over all of the crystallites at different orientations in the sample.

195. The averaging of the anisotropy energy of individual crystals to determine an effective average anisotropy energy for a polycrystalline sample is described by G. Herzer, "Grain size dependence of coercivity and permeability in nanocrystalline ferromagnets," *IEEE Trans. Magn.*, vol. 26, no. 5, pp. 1397-1402, Sept. 1990 (produced by Seagate at SEA01974948). Herzer assumed that the orientations of the crystals in a sample was fully random (equal volumes present at all orientation angles). *See id.* at 1399-1400. For such a film, the average magnetocrystalline anisotropy energy would be constant as a function of angle and not display a maximum or a minimum. However, local statistical variations in the orientation of the crystals would result in small, but non-zero anisotropies in local regions that could pin domain walls and result in coercivity, and this local fluctuation would result in a local anisotropy that could be related to coercivity and grain size by the following equation:

$$H_c = p_c \frac{\langle K \rangle}{J_s} \approx p_c \frac{K_1^4 \cdot D^6}{J_s \cdot A^3} \qquad (5a)$$

See id. at 1400 (equation 5(a)). *See also* citations to Herzer in Mathieu et al., "Magnetic Anisotropy Dispersion in FeCo Films," *IEEE Trans. Magn.*, vol. 44, no. 4, Apr. 2008; Mathieu, et al., "Within wafer magnetic anisotropy in sputtered FeCo films," *J. App. Physics*, vol. 103, no. 07E715, 2008; SEA01134746 at 750; SEA00019292 at 307; SEA00027744 at 752; SEA00409798 at 607; SEA01134854 at 856; SEA01134932 at 934; SEA01941843 at 858; SEA01963227 at 233; SEA01986461 at 466; SEA01991054 at 069; SEA01991416 at 421; SEA01993371 at 376; SEA02033892 at 896; SEA02064462 at 470; SEA02066314 at 321;

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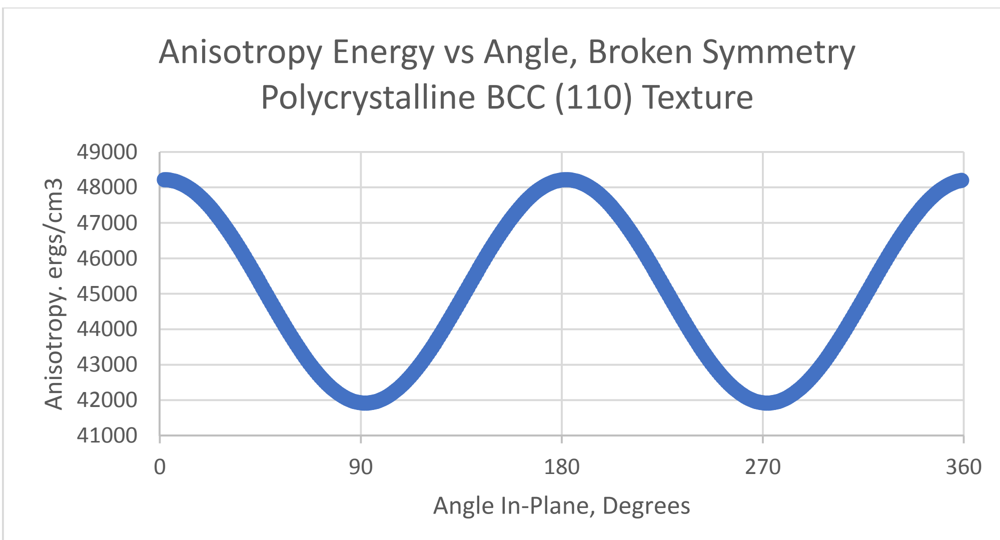
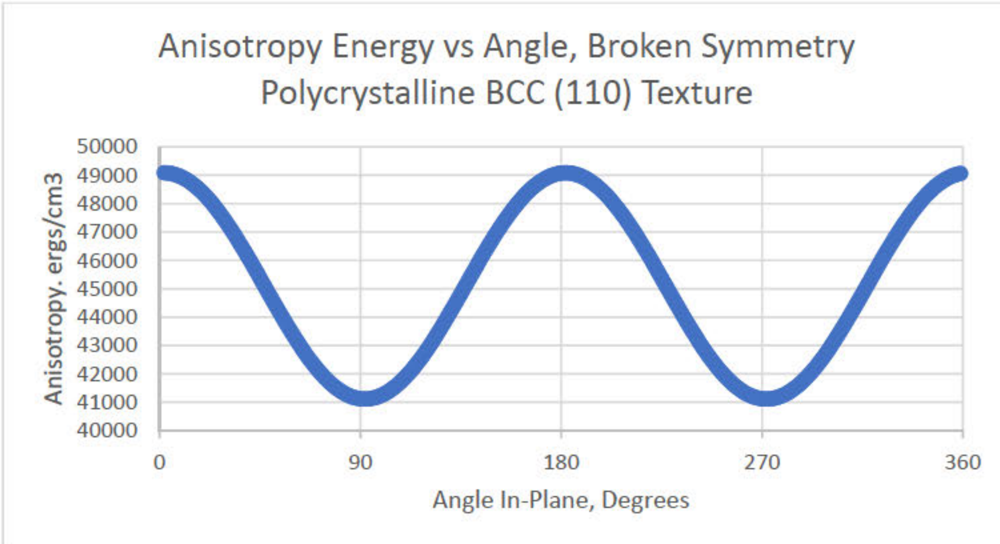
SEA02075274 at 276; SEA02078700 at 852; SEA02136396 at 401; SEA02303156 at 163; SEA02550841 at 847; SEA02588509 at 518.

196. I conclude that the [redacted] Products contain lower FeCo layers that are "uniaxial symmetry broken" under the Court's construction of that term and its constituent parts, "uniaxial" and "symmetry broken structure." I calculated the magnetocrystalline anisotropy energy density as a function of angle for the SOGPPC and S2MMMC samples. The relative areas of crystals as a function of <100> orientation was calculated using the equation for the sinusoidal variation above and this was used to provide a weighted average of the magnetocrystalline energy density as a function of angle, averaging over 360 degrees of crystal orientation. The resulting average magnetocrystalline energy density as a function of angle for sample SOGPPC is shown below (*see* Appendix F):



The resulting average magnetocrystalline energy density as a function of angle for sample S2MMMC is shown below (*see* Appendix G):



Both of these samples are representative of the [redacted] head products. For the calculation of these magnetocrystalline anisotropy energy density functions, I utilized a value for the anisotropy constant, K_1, as determined below.

197. It is my opinion that this anisotropy energy density function is uniaxial under the Court's construction of the term "uniaxial" because it has a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis. Additionally, because this uniaxial anisotropy energy density function was determined solely by utilizing dark field imaging data that reflects the unequal amounts of the bcc-d variants of a six variant system, it is my opinion that the lower FeCo layers in the [redacted] Products are uniaxial as a result of being symmetry broken and, accordingly, meet the Court's construction of the term "uniaxial symmetry broken."

198. It is my opinion that the [redacted] Products include lower FeCo layers that are a uniaxial symmetry broken structure in accordance with the requirements of claim 1 of the '988 patent.

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199. For the calculation of these magnetocrystalline anisotropy energy density functions, I utilized a value for the anisotropy constant, K_1, as determined for $Fe_{65}Co_{35}$ of 2.06 x 10^5 erg/cm^3 I determined this value by averaging the two values provided by Hall in his published works *See* Hall, R.C., "Single Crystal Anisotropy and Magnetostriction Constants of Several Ferromagnetic Materials Including Alloys of NiFe, SiFe, AlFe, CoNi, and CoFe," *J. of Applied Physics*, 30, 816-19 (1959) ("Hall 1959") and Hall, R.C., "Magnetic Anisotropy and Magnetostriction of Ordered and Disordered Cobalt-Iron Alloys," *Trans. of the Metallurgical Soc. of AIME*, 218 (April 1960) ("Hall 1960"). Also, I assumed, following the guidance of Hall, that a separate contribution from K_2 was not needed to describe the magnetocrystalline anisotropy of these alloys. As discussed in Hall 1959 (Hall, R.C., "Single Crystal Anisotropy and Magnetostrition Constants of Several Ferromagnetic Materials Including Alloys of NiFe, SiFe, AlFe, CoNi, and CoFe," *J. of Applied Physics*, 30, 816-19 (1959) ("Hall 1959")), anisotropy energy minima present in the <100> directions for a disk sample prepared with {110} faces is not sensitive to K_2. However, the anisotropy maxima in the (110) plane are known to be essentially additive in K_1 and K_2, although the K_2 contribution is weighted much more weakly. From this it is understood that Hall's experimental report of only a value for K_1 must necessarily include the contributions of both K_1 and K_2 (if not negligible) to the magnetocrystalline anisotropy energy maxima experimentally observed.

200. To confirm that my calculations of the anisotropy energy density function based on dark field data collected from a sample [redacted] Product was correct, I considered carefully the appropriate value of the anisotropy constant, K_1, that I used, and the propriety of my assumption that K_2 is negligible in the case of FeCo at [redacted] *See,*

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[redacted]

201. The available values for the magnetocrystalline anisotropy constants for bcc FeCo alloys in the compositional range of interest (65% Fe and 35% Co) are provided from the work of Hall. *See* Hall 1959; Hall 1960. Hall used a torque magnetometer designed by Byrnes (*see* Byrnes, W.S. and R.G. Crawford, "Improved Torque Magnetometer," *J. of Applied Physics*, 29, 493-95 (1958) ("Byrnes")) for these measurements, and used single crystal samples formed as disks between (110) planes, hence these measurements are very appropriate for calculation of anisotropy energy density variation in the crystallographic (110) plane, as I have performed here. The instrument used by Hall provided a plot of torque as a function of angle on a strip chart recorder and was described by Hall as having a torque accuracy of 2%. *See* Hall, R.C., "The Effect of the Order-Disorder Reaction on the Magnetic Anisotropy and Magnetostriction of Single Crystals of the Ferromagnetic Aluminum-Iron Alloys," *Trans. of the Metallurgial Soc. of AIME*, October 1958, 703-06 ("Hall 1958").

202. The figure below illustrates the torque curve expected for the measurement performed by Hall as a solid black line for a sample having the second anisotropy constant, K_2, equal to zero. Also shown are torque curves corresponding to large, non-zero values of K_2, equal to + K_1 and – K_1, as red dotted and blue dashed lines, respectively. For purposes of comparison of the three curves, they have been scaled to have the same maximum (near 27 and 205 degrees) and minimum values (near 154 and 334 degrees) of the torque amplitude. However, the minor maxima and minima are clearly different in the three cases, being 32% higher for the torque curve corresponding to $K_2 = K_1$ and 39% lower for the torque curve corresponding to $K_2 = -K_1$. Such large positive and negative values of K_2 result in torque differences that are more than 15

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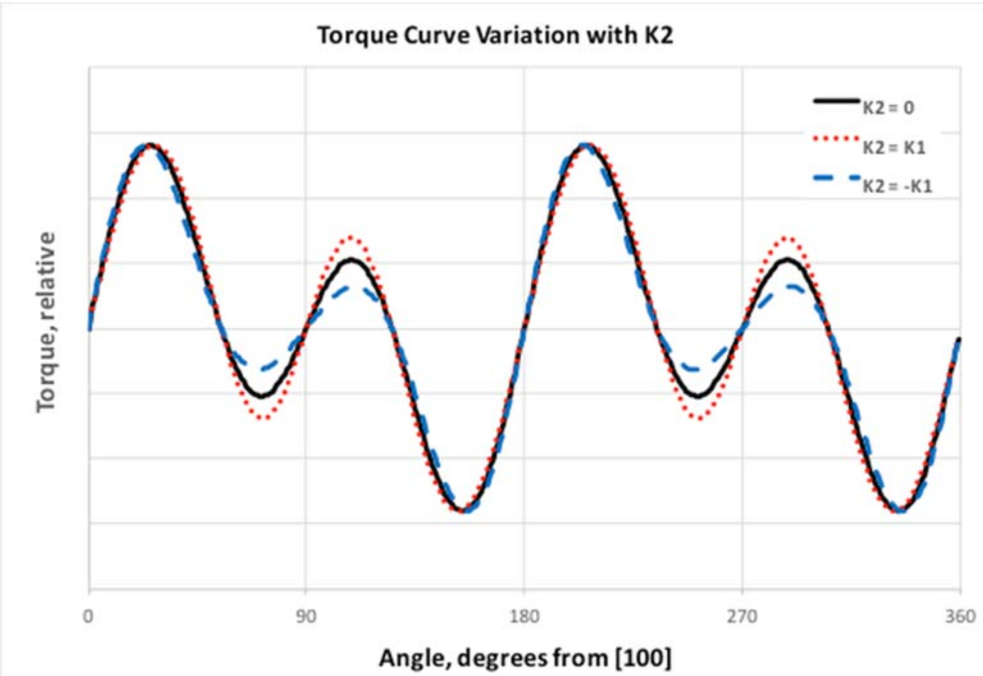
times greater the measurement accuracy and would certainly have been observed by Hall. My underlying calculations for preparing this figure are provided in Appendix E.



203. As Hall failed to report a value for K_2 from his experimental measurements, and he would have readily detected a relatively large value of K_2, we can conclude that such large K_2 values were not observed by Hall. Most likely, K_2 was positive or negative and near 10 % to 20% of K_1 in magnitude, as is reported for Fe and Fe-Al alloys. *See* Hall, R.C., "The Effect of the Order-Disorder Reaction on the Magnetic Anisotropy and Magnetostriction of Single Crystals of the Ferromagnetic Aluminum-Iron Alloys," *Trans. of the Metallurgial Soc. of AIME*, October 1958, 703-06 ("Hall 1958"). Our assumption that K_2 is negligible in comparison to K_1 to calculate the magnetocrystalline anisotropy energy density of FeCo alloys in the (110) plane is justified by Hall's choice to omit reports of K_2 in his publication of the K_1 values based on measurements made in the (110) plane of FeCo alloy samples. This is further supported by Hall's citation to Kouvel (*see* Kouvel, J.S. and C.D. Graham, "On the Determination of Magnetocrystalline Anisotropy Constants from Torque Measurements," *J. of Applied Physics*,

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28, 340-43 (1957)), wherein Kouval points out that small measurement errors in K_1 can appears as large relative changes for K_2. *See* Kouvel, J.S. and C.D. Graham, "On the Determination of Magnetocrystalline Anisotropy Constants from Torque Measurements," *J. of Applied Physics*, 28, 340-43 (1957). Accordingly, I concluded that my use of K_1 as calculated by Hall and determination that K_2 was negligible were proper.

204. [redacted]

205. [redacted]

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[redacted]

206. [redacted]

207. [redacted]

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[redacted]

208. [redacted]

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[redacted]

209. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

210. As discussed above, it is my understanding that the lower layer of FeCo in the [redacted] Products forms a symmetry broken structure. Additionally, as my analysis of dark field imaging data obtained by Dr. Clark establishes, material in the lower layer of FeCo in the write pole of [redacted] Products is uniaxial as a result of the being symmetry broken and, accordingly, it is my opinion that the [redacted] Products include material that forms a uniaxial symmetry broken structure. Therefore, it is my opinion that element (c) of claim 1 of the '988 patent is literally met by the [redacted] Products.

e) Alternatively, the "uniaxial" limitation is met by the [redacted] Products pursuant to the doctrine of equivalents

211. Alternatively, it is my opinion that the [redacted] Products infringe claim 1 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents and, as I have explained above, all of the other limitations of claim 1 of the '988 patent are literally present in the [redacted] Products.

212. It is my opinion that the "uniaxial" limitation is infringed under the doctrine of equivalents because the [redacted] Products contain a lower FeCo layer that performs substantially the same function in substantially the same way to achieve substantially the same result as the claimed "uniaxial" limitation. I understand that Seagate may argue that, contrary to the Court's construction of "uniaxial," claim 1 requires that the bcc-d layer must exhibit uniaxial magnetic anisotropy due to symmetry breaking that dominates any other anisotropy that may be present or

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is the sole source of anisotropy in the bcc-d layer. While I disagree with this interpretation that adds a requirement to the Court's construction of "uniaxial," even if this interpretation were correct, evidence that I have provided in this Report shows that there are insubstantial differences between this interpretation of the requirements of the claims of the '988 patent and the attributes of the [redacted] Products.

213. Specifically, the function performed by "uniaxial" anisotropy is causing the bcc-d material to exhibit uniaxial magnetic properties. This function is being performed in the region of the lower FeCo layer in the [redacted] Products measured by dark field data analysis (*see* Section VI.1.d.) showing the measured region of the lower FeCo layer to be uniaxial due to symmetry breaking. Even if other anisotropies were present that enhanced or contradicted this measured intrinsic uniaxial anisotropy, the intrinsic uniaxial anisotropy caused by symmetry breaking performs substantially the same function of causing the bcc-d material to exhibit uniaxial magnetic properties.

214. Furthermore, the function of the "uniaxial" limitation is performed in substantially the same way regardless of whether other anisotropy is present—the contribution of uniaxial anisotropy due to symmetry breaking persists regardless of whether there are enhancing or contradicting anisotropies present, such as shape or stress anisotropy. This is supported by the dark field analysis which accounts solely for the uniaxial anisotropy due to symmetry breaking, regardless of any other anisotropies present. *See* Section VI.1.d. Thus, regardless of whether other anisotropies are present in the lower FeCo layer of the [redacted] Products, this intrinsic uniaxial anisotropy due to symmetry breaking (*i.e.*, breaking the symmetry of a six-variant system such that the symmetry breaking is a cause of the uniaxial magnetic behavior in the

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material) contributes towards the lower FeCo layer exhibiting substantially uniaxial magnetic properties in the region analyzed.

215. Also, the result of this intrinsic uniaxial anisotropy due to symmetry breaking is substantially the same regardless of whether enhancing or contradicting sources of anisotropy are present in the lower FeCo layer. Even if other anisotropies are present, the intrinsic uniaxial anisotropy due to symmetry breaking substantially provides improved magnetic properties and a preferred magnetic orientation in the write pole. In sum, any differences between the magnetic anisotropy of the lower FeCo layer in the [redacted] Products and the claimed uniaxial material are insubstantial because the lower FeCo layer has intrinsic uniaxial anisotropy due to symmetry breaking in the lower FeCo layer. *See* Section VI.1.d. That the lower FeCo layer may have other contributors to its magnetic anisotropy, such as shape anisotropy or stress anisotropy, does not change the fact that the [redacted] Products achieve uniaxial magnetic properties as a result of symmetry breaking in the lower FeCo layer. As discussed above in Section VI.1.d, the presence of intrinsic uniaxial anisotropy in the lower FeCo layer due to symmetry breaking performs the desirable function of improving magnetic performance and mitigating undesirable attributes of a write pole material, such as Erase After Write.

216. A person having ordinary skill in the art would be aware that, for a magnetic thin film material, magnetic anisotropies are additive. Moreover, a person having ordinary skill in the art would be aware that shape anisotropy can be introduced by changing the shape of a magnetic thin film and, consequently, shape anisotropy may be introduced in a predictable manner without affecting the claimed anisotropy due to symmetry breaking. Similarly, a person having ordinary skill in the art would be aware of the possible addition of other types of anisotropy, such as stress anisotropy. As discussed in Section II.A., the '988 patent concerns the

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uniaxial magnetic anisotropy that results in a bcc-d material due to symmetry breaking. Therefore, so long as the bcc-d layer exhibits uniaxial anisotropy as a result of symmetry breaking, it meets claim 1 of the '988 patent and the presence of other types of anisotropy amount to an insubstantial difference.

217. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation by the doctrine of equivalents.

218. Based on all of the information discussed above and in Section VI.1.d., it is my opinion that, to the extent the "uniaxial" limitation is not literally satisfied by the [redacted] Products, this limitation is met pursuant to the doctrine of equivalents. Accordingly, claim 1 of the '988 patent is infringed by the [redacted] Products under the doctrine of equivalents.

f) Element (d) of Claim 1, "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer," is met by the [redacted] Products

219. Element (d) of claim 1 of the '988 patent provides "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer."

220. Element (d) is literally met by the [redacted] Products. Specifically, the write pole of the [redacted] Products contains two layers of NiFe. The lower layer of NiFe serves as an atomic template because it provides an atomic pattern upon which the lower layer of FeCo is grown and directs this growth of the lower layer of FeCo. Moreover, as discussed further below, I understand that the lower layer of NiFe is predominately (111) hexagonal by virtue of having a fcc crystal structure and a predominantly (111) texture. The lower layer of NiFe is also disposed between the substrate (the AlTiC wafer material discussed in Section VI.1.b. above) and the bcc-

d layer (the lower layer of FeCo, which has a (110) bcc crystal structure, as discussed in Section VI.1.c. above).

221. [redacted]

222. [redacted]

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223. [redacted]

224. As discussed above, I understand that the presence of the two NiFe layers in the write pole of the [redacted] Products has been confirmed by EDS analysis performed on representative samples S0GPPC and S2MMMC. *See* Clark Report at Sections F.1.a.1. and F.1.b.1. The presence of both the lower and upper NiFe layers can be observed in the images below. The first image below depicts sample S0GPPC, and the second image shows sample S2MMMC.

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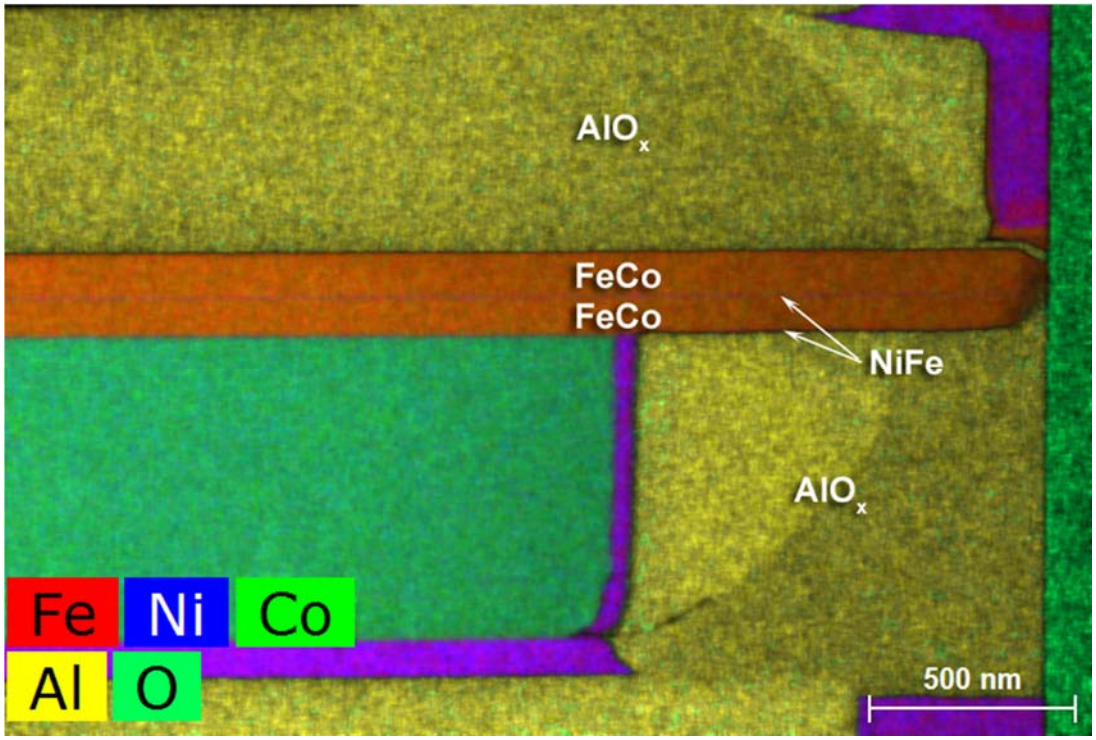

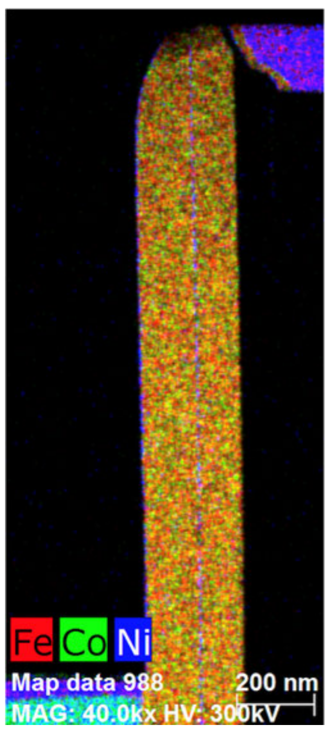

The presence of the NiFe layers are also observable below in the EDS maps showing Ni. The first image below depicts sample S0GPPC, and the second image shows sample S2MMMC.

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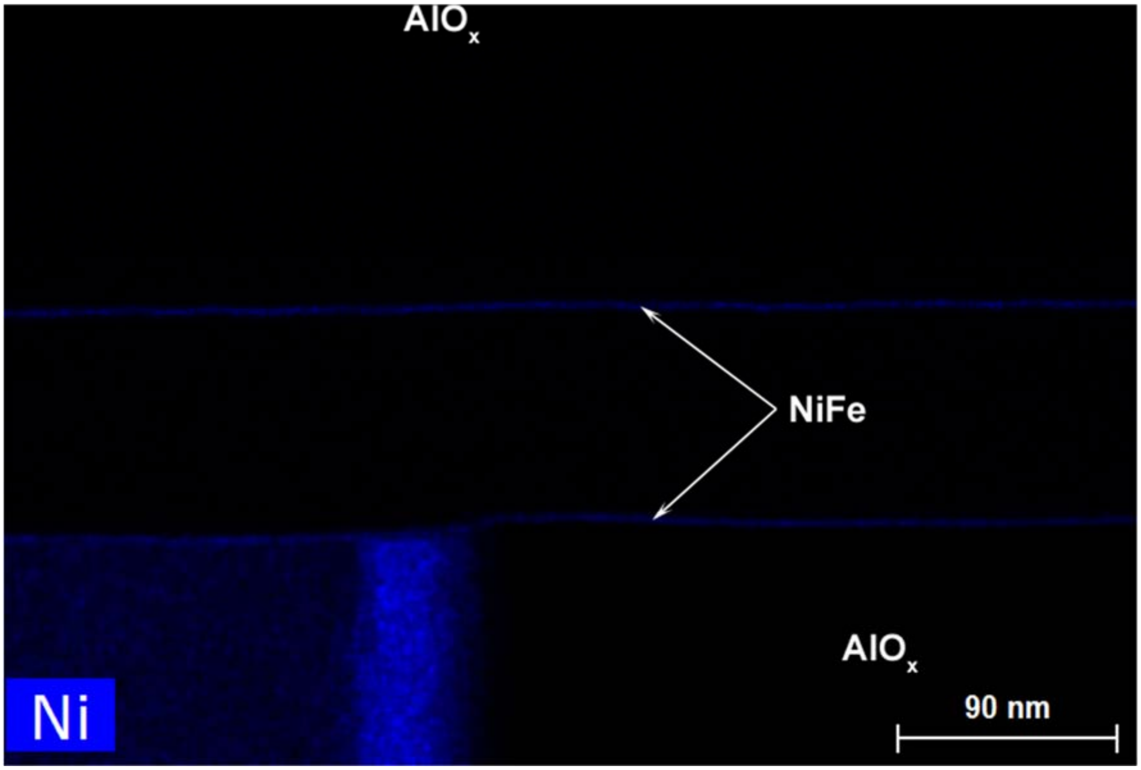

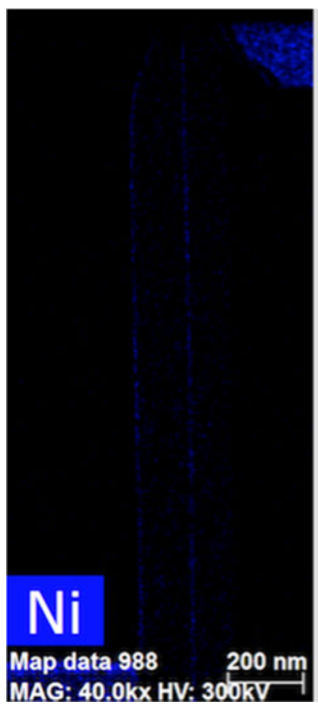

225. I further understand that Dr. Clark was able to conclude that the lower NiFe layer has an fcc crystal structure with its (111) planes parallel to the lower FeCo layer deposited above it. *See* Clark Report at Sections F.1.a.3. and F.1.b.3. Such a (111) oriented fcc crystal structure

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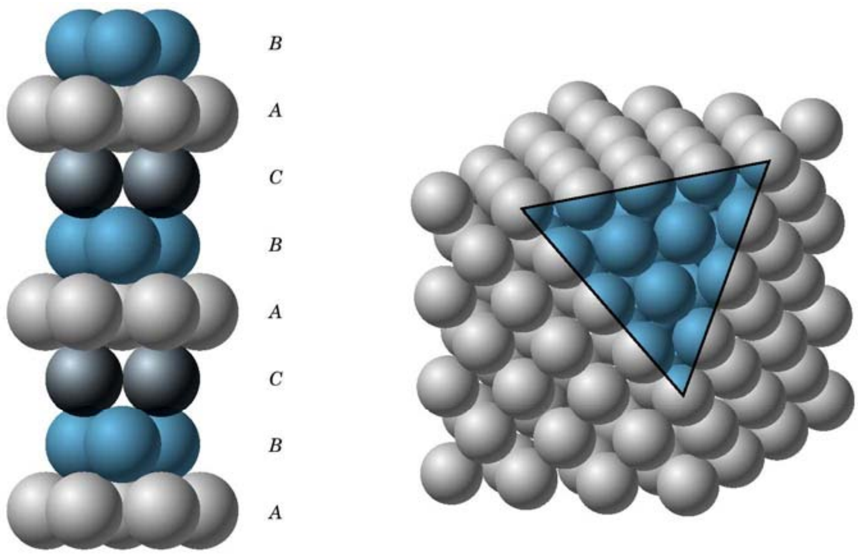
presents a (111) hexagonal surface on which the lower FeCo layer is grown. '988 patent at 14:55-57 ("The (111) textured fcc, (111) textured fcc derivative, or an (0002) textured hcp crystals are examples of the (111) textured hexagonal atomic template."). An illustration to show the hexagonal pattern present in the (111) plane of an fcc crystal is below.



(a) (b)

FIGURE 3.15 (*a*) Close-packed stacking sequence for face-centered cubic. (*b*) A corner has been removed to show the relation between the stacking of close-packed planes of atoms and the FCC crystal structure; the heavy triangle outlines a (111) plane. (Figure *b* from W. G. Moffatt, G. W. Pearsall, and J. Wulff, *The Structure and Properties of Materials,* Vol. I, *Structure,* p. 51. Copyright © 1964 by John Wiley & Sons, New York. Reprinted by permission of John Wiley & Sons, Inc.)

Callister at Fig. 3.15

226. I understand that Dr. Clark used FFTs to conclude that, for sample S0GPPC, the $(111)_{NiFe}$ plane is parallel to the $(110)_{FeCo}$ plane for the lower layers of each of NiFe and FeCo. *See* Clark Report at Section F.1.a.3. This relationship is characteristic of an epitaxial relationship between the fcc NiFe in the lower layer of NiFe and the bcc FeCo in the lower layer of FeCo. The existence of this epitaxial relationship indicates that the lower NiFe layer directs the growth of its overlying layer—that is, the lower FeCo layer. Further, I understand that this is the epitaxial orientation relationship characteristic of the Kurdjumov-Sachs six variant system was

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present in the lower FeCo and NiFe layers. *See id*. Accordingly, the lower NiFe layer in sample S0GPPC directs the growth of the lower FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system. As discussed above, sample S0GPPC is representative of the [redacted] Products (*see* Section VI.1.a.) and, accordingly, I conclude that each of the [redacted] Products has a lower layer of NiFe that directs the growth of the lower FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system.

227. Similarly, I understand that Dr. Clark used FFTs to conclude that, for sample S2MMMC, the $(111)_{NiFe}$ plane is parallel to the $(110)_{FeCo}$ plane for the lower layers of each of NiFe and FeCo. *See* Clark Report at Section F.1.b.3. This relationship is characteristic of an epitaxial relationship between the fcc NiFe in the lower layer of NiFe and the bcc FeCo in the lower layer of FeCo. The existence of this epitaxial relationship indicates that the lower NiFe layer directs the growth of its overlying layer—that is, the lower FeCo layer. Further, I understand that this is the epitaxial orientation relationship characteristic of the Kurdjumov-Sachs six variant system was present in the lower FeCo and NiFe layers. *See id*. Accordingly, the lower NiFe layer in sample S2MMMC directs the growth of the lower FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system. As discussed above, sample S2MMMC is representative of the [redacted] Products (*see* Section VI.1.a.) and, accordingly, this further supports my conclusion that each of the [redacted] Products has a lower layer of NiFe that directs the growth of the lower FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system.

228. [redacted]

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[redacted]

229. [redacted]

230. [redacted]

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[redacted]

231. [redacted]

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[redacted]

232. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

233. Therefore, the [redacted] Products include at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer, which is the lower NiFe layer in the write pole. Thus, it is my opinion that element (d) of claim 1 of the '988 patent is literally met by the [redacted] Products.

2. Opinion No. 16: The [redacted] Products Infringe Claim 3 of the '988 Patent

a) Claim 3, "[t]he magnetic material structure recited in claim 1, wherein a surface of said substrate is amorphous or polycrystalline," is met by the [redacted] Products

234. Claim 3 of the '988 patent provides ""[t]he magnetic material structure recited in claim 1, wherein a surface of said substrate is amorphous or polycrystalline."

235. Claim 3 is literally met by the [redacted] Products. The [redacted] Products all include an AlTiC wafer that serves as the substrate, *see* Sections VI.1.a. and VI.1.b., and has a polycrystalline surface. The polycrystalline nature of the entirety of the AlTiC substrate,

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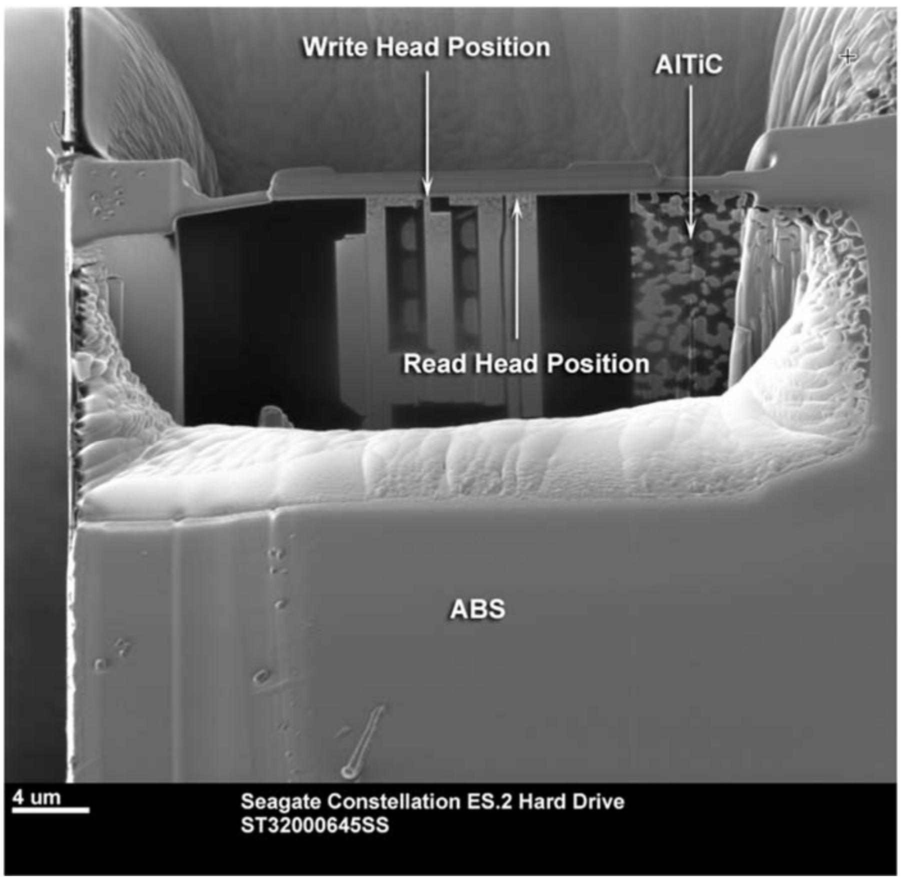
including its surface, is observable in representative [redacted] Products, specifically samples S0GPPC and S2MMMC, via imaging in a FEI 200 TEM FIB gallium focused ion beam ("FIB") system during lift out of a cross-section sample. In the image below, the AlTiC wafer substrate is visible on the right of the image for sample S0GPPC, and on the left for sample S2MMMC, and the material layers comprising the head, including the write pole, deposited on top of the AlTiC wafer substrate are visible to the left for S0GPPC and to the right for S2MMMC. The first image below depicts sample S0GPPC, and the second image shows sample S2MMMC.



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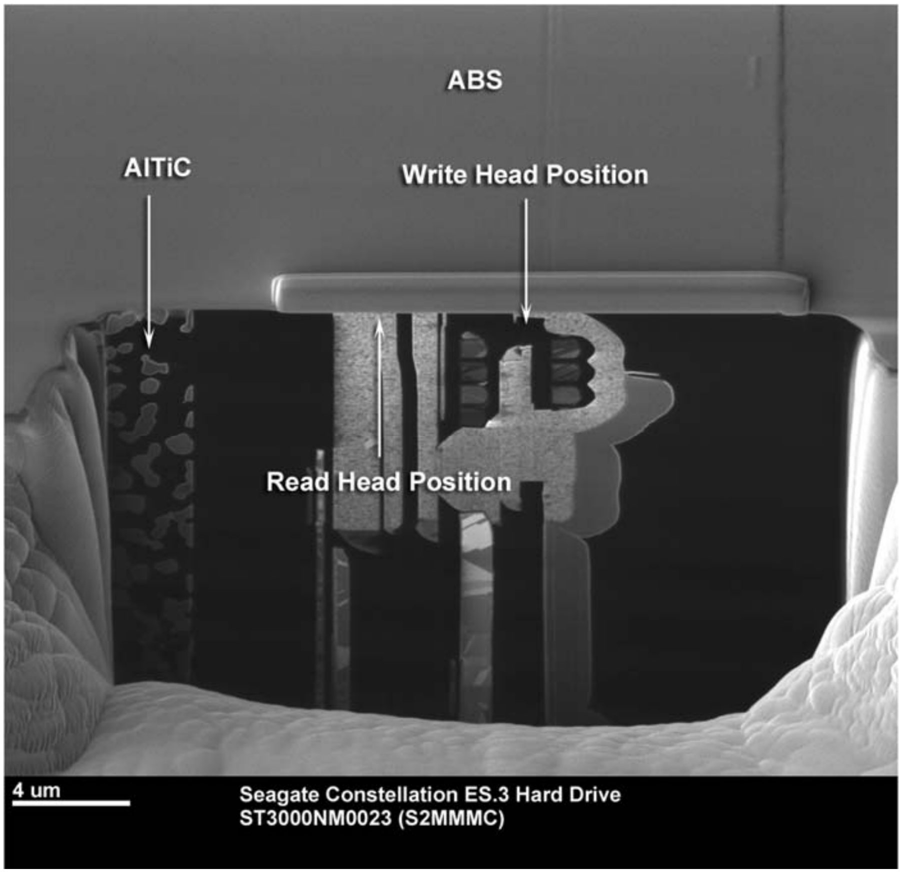

236. [redacted].

237. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

238. Based on reverse engineering of a representative [redacted] Product and Seagate's internal documentation, it is my opinion that claim 3 of the '988 patent is literally infringed by the [redacted] Products.

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3. Opinion No. 17: The [redacted] Products Infringe Claim 6 of the '988 Patent

a) Claim 6, "[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is formed from a fcc-d or hcp crystalline material," is met by the [redacted] Products

239. Claim 6 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is formed from a fcc-d or hcp crystalline material."

240. Claim 6 is literally met by the [redacted] Products. As discussed above, Dr. Clark analyzed the lower layer of NiFe in representative [redacted] Products, specifically samples S0GPPC and S2MMMC, through high resolution TEM imaging of a cross section and FFT analyses confirmed that the lower layer of NiFe had a fcc crystal structure, which is an fcc-d crystal structure under the Court's construction. *See* Clark Report at Sections F.1.a.2, F.1.a.3, F.1.b.2, and F.1.b.3.

241. [redacted]

242. [redacted]

243. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

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244. Based on reverse engineering of a representative [redacted] Product and Seagate's internal documentation and witness testimony, it is my opinion that claim 6 of the '988 patent is literally infringed by the [redacted] Products.

4. Opinion No. 18: The [redacted] Products Infringe Claim 7 of the '988 Patent

a) Claim 7, "[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is magnetic," is met by the [redacted] Products

245. Claim 7 of the '988 patent provides ""[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is magnetic."

246. [redacted]

247. [redacted]

248. [redacted]

249. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

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250. Based on reverse engineering of a representative [redacted] Product and Seagate's internal documentation and witness testimony, it is my opinion that claim 7 of the '988 patent is literally infringed by the [redacted] Products.

5. Opinion No. 19: The [redacted] Products Infringe Claim 9 of the '988 Patent

a) Claim 9, "[t]he magnetic material structure according to claim 1, further comprising: a second layer providing a (111) textured hexagonal atomic template, wherein said second layer is magnetic," is met by the [redacted] Products

251. Claim 9 of the '988 patent provides "[t]he magnetic material structure according to claim 1, further comprising: a second layer providing a (111) textured hexagonal atomic template, wherein said second layer is magnetic."

252. Specifically, the write pole of the [redacted] Products contains two layers of NiFe. The lower layer of NiFe is the first (111) textured hexagonal atomic template and was discussed in Section VI.1.f. above. The upper layer of NiFe in the write pole of the [redacted] Products serves as a second layer that provides an atomic template because it provides an atomic pattern upon which the upper layer of FeCo is grown and directs this growth of the upper layer of FeCo. Moreover, as discussed further below, I understand that the upper layer of NiFe is predominately (111) hexagonal by virtue of having a fcc crystal structure and a predominantly (111) texture. The upper layer of NiFe is also disposed between the substrate (the AlTiC wafer material discussed in Section VI.1.b. above) and the upper layer of FeCo.

253. [redacted]

[redacted]

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[redacted]

254. [redacted]

255. [redacted]

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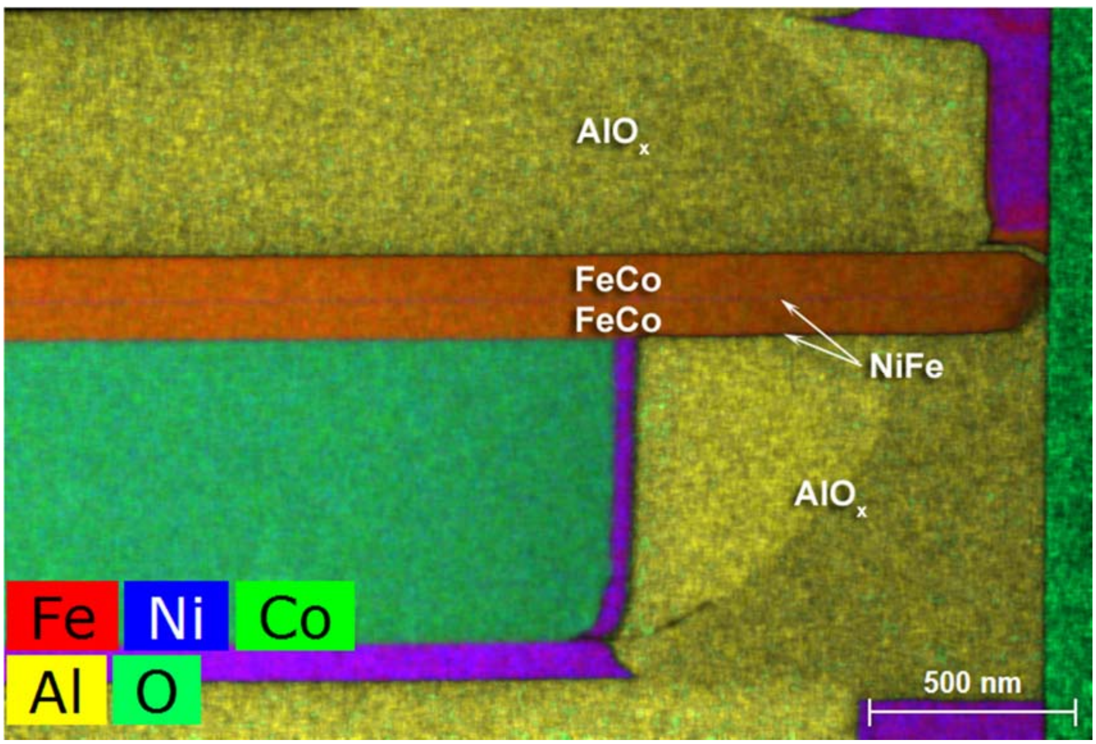
[redacted]

256. As discussed above, I understand that the presence of the two NiFe layers in the write pole of the [redacted] Products has been confirmed by EDS analysis performed on representative sample S0GPPC. *See* Clark Report at Section F.1.a.1. The presence of both the lower and upper NiFe layers can be observed in the images below.



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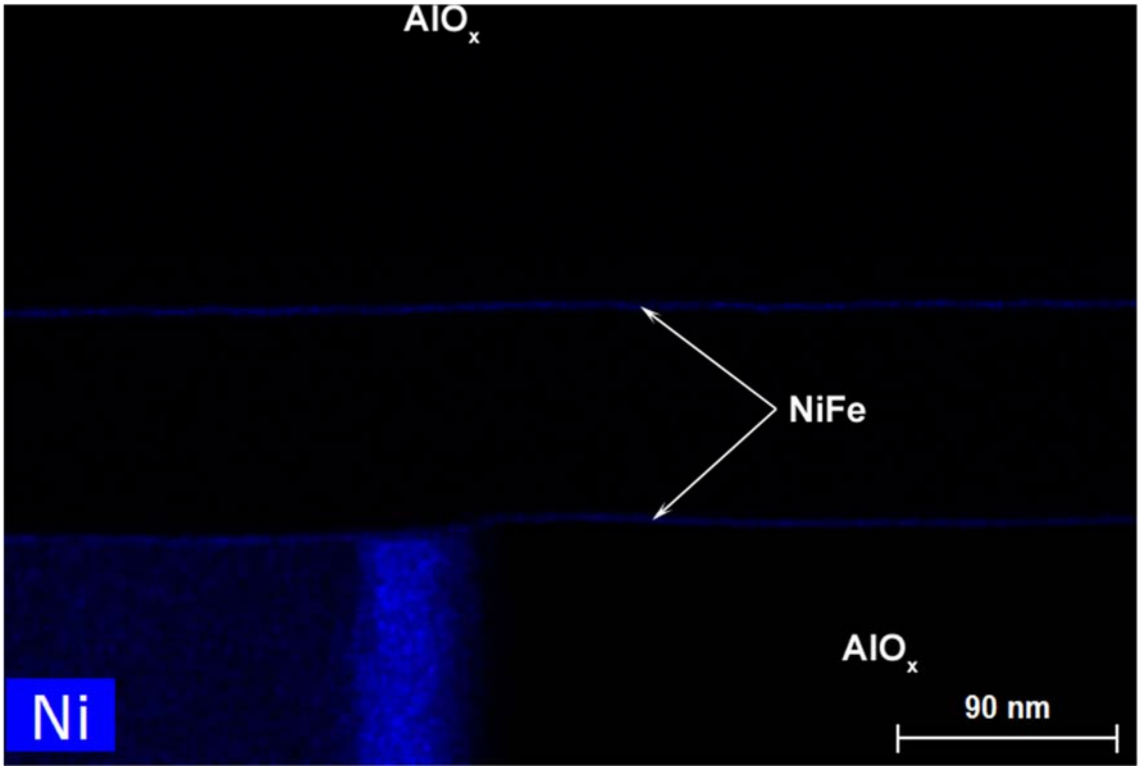

257. I understand that the presence of the two NiFe layers in the write pole of the [redacted] Products has also been confirmed by EDS analysis performed on representative sample S2MMMC. *See* Clark Report at Section F.1.b.1. The presence of both the lower and upper NiFe layers can be observed in the images below.

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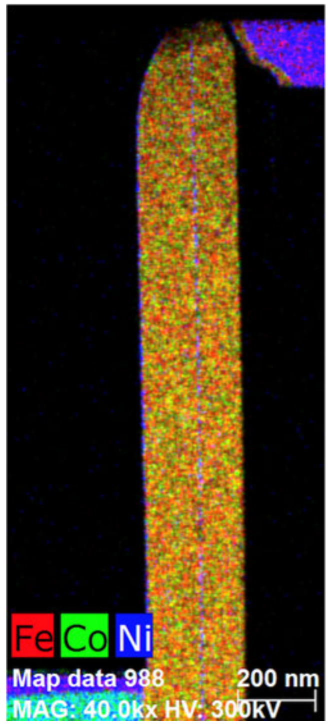

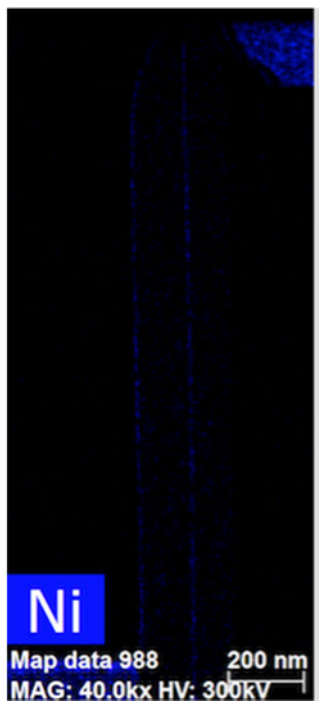

258. I further understand that Dr. Clark concluded that the upper NiFe layer in samples S0GPPC and S2MMMC has an fcc crystal structure with its (111) planes parallel to the upper FeCo layer deposited above it. *See* Clark Report at Sections F.1.a.3 and F.1.b.3. Such a (111)

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fcc crystal structure presents a (111) hexagonal surface on which the upper FeCo layer is grown. Callister at Fig. 3.15; '988 patent at 14:55-57 ("The (111) textured fcc, (111) textured fcc derivative, or an (0002) textured hcp crystals are examples of the (111) textured hexagonal atomic template."). I understand that FFTs performed on TEM images from a cross-section of sample S0GPPC showed that the $(111)_{NiFe}$ plane is parallel to the $(110)_{FeCo}$ plane for the upper layers of each of NiFe and FeCo. *See* Clark Report at Section F.1.a.3. This relationship is characteristic of an epitaxial relationship between the fcc NiFe in the upper layer of NiFe and the bcc FeCo in the upper layer of FeCo. The existence of this epitaxial relationship indicates that the upper NiFe layer directs the growth of its overlying layer—that is, the upper FeCo layer. Further, I understand that this FFT analysis indicated that a $<110>_{NiFe}$ direction is parallel to a $<111>_{FeCo}$ direction, *i.e.*, the epitaxial orientation relationship characteristic of the Kurdjumov-Sachs six variant system was present in the upper FeCo layer. *See id*. Accordingly, the upper NiFe layer in sample S0GPPC directs the growth of the upper FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system. As discussed above, samples S0GPPC and S2MMMC are representative of the [redacted] Products (*see* Section VI.1.a.) and, accordingly, I conclude that each of the [redacted] Products has an upper layer of NiFe that directs the growth of the upper FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system.

259. [redacted]

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[redacted]

260. [redacted]

261. [redacted]

262. [redacted]

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[redacted]

263. Therefore, the [redacted] products include at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer, which is the upper NiFe layer in the write pole. Thus, it is my opinion that claim 9 of the '988 patent is literally infringed by the [redacted] Products.

6. Opinion No. 20: The [redacted] Products Infringe Claim 17 of the '988 Patent

a) Claim 17, "[t]he magnetic material structure recited in claim 1, wherein said bcc-d layer forming a uniaxial symmetry broken structure is composed of Fe or FeCo or an alloy of Fe or FeCo," is met by the [redacted] Products

264. Claim 17 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein said bcc-d layer forming a uniaxial symmetry broken structure is composed of Fe or FeCo or an alloy of Fe or FeCo."

265. [redacted]

266. [redacted]

267. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

268. Based on reverse engineering of a representative [redacted] Product and Seagate's internal documentation and witness testimony, it is my opinion that claim 17 of the '988 patent is literally infringed by the [redacted] Products.

7. Opinion No. 21: The [redacted] Products Infringe Claim 19 of the '988 Patent

a) Claim 19, "[t]he magnetic material structure recited in claim 1, wherein the layer material forming said (111) textured hexagonal atomic template is composed of Ag, Al, Au, Cu, fcc-Co, fcc-CoCr, Ir, Ni, NiFe, Pt, Rh, Pd, hcp-Co, Gd, Re, Ru, Tb, Ti, or alloys of one of these materials combined with at least one element," is met by the [redacted] Products

269. Claim 19 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein the layer material forming said (111) textured hexagonal atomic template is composed of Ag, Al, Au, Cu, fcc-Co, fcc-CoCr, Ir, Ni, NiFe, Pt, Rh, Pd, hcp-Co, Gd, Re, Ru, Tb, Ti, or alloys of one of these materials combined with at least one element."

270. [redacted]

271. [redacted]

272. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and FeCo layers in the write pole of the [redacted] Products meet this limitation.

273. Based on reverse engineering of a representative [redacted] Product and Seagate's internal documentation and witness testimony, it is my opinion that claim 19 of the '988 patent is literally infringed by the [redacted] Products.

8. Opinion No. 22: The [redacted] Products Infringe Claim 27 of the '988 Patent

274. It is my opinion that the [redacted] Products infringe claim 27 of the '988 patent. It is my opinion that every element of claim 27 is literally met by the [redacted] Products. I explain the foundation for my opinion on an element-by-element basis in Sections VI.8.a. through VI.8.f. below. Alternatively, it is my opinion that the [redacted] Products infringe claim 27 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents. Accordingly, claim 27 is infringed by the [redacted] Products where "uniaxial" is met pursuant to the doctrine of equivalents and all other limitations are literally present.

275. I understand that the Court construed certain terms in claim 27 of the '988 patent. Specifically, I understand that the Court construed six terms from the claims of the '988 patent as reflected in the table below.

Term	Construction
"atomic template"	An atomic pattern upon which material is grown and which is used to direct the growth of an overlying layer
"[Layer] providing a (111) textured hexagonal atomic template"	Layer that is predominately (111) hexagonal and that provides an atomic template
"Uniaxial"	Having an anisotropy energy density function with only a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis
"Symmetry broken structure"	A structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system
"Uniaxial symmetry broken structure"	A structure that is uniaxial as a result of the structure being symmetry broken

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Term	Construction
"Variant/orientational variant" "Variants/orientational variants"	One of a set of possible crystal orientations Two or more of a set of possible crystal orientations
"bcc-d"	Either a body centered cubic or a body centered cubic derivative crystal structure
"fcc-d"	Either a face centered cubic or a face centered cubic derivative crystal structure

See Claim Construction Order, dated October 18, 2017, at 7-8. I have applied the Court's constructions for all construed terms in my infringement analysis. I have applied the plain and ordinary meaning according to a person having ordinary skill in the art to all non-construed terms.

a) To the extent the preamble to claim 27, "[a] magnetic device having incorporated therein a magnetic material structure comprising" is limiting, it is met by the [redacted] Products

276. The preamble of claim 27 of the '988 patent states "[a] magnetic device having incorporated therein a magnetic material structure comprising."

277. I understand that the preamble to a patent claim is generally not limiting. I further understand that Seagate has not sought construction of the preamble to claim 27 of the '988 patent and has not asserted that it is limiting. Nevertheless, the [redacted] Products are magnetic devices having incorporated therein a magnetic material structure.

278. [redacted]

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[redacted]

279. Thus, it is my opinion that, to the extent the preamble of claim 27 is limiting, it is met by the [redacted] Products.

b) Element (a) of Claim 27, "a substrate," is met by the [redacted] Products

280. Element (a) of claim 27 of the '988 patent provides "a substrate." This is the same language as the element (a) of claim 1 of the '988 patent.

281. Element (a) is literally met by the [redacted] Products. Specifically, the [redacted] Products include a substrate, for all of the reasons listed in Section VI.1.b. above. Thus, it is my opinion that element (a) of claim 27 is met by the [redacted] Products.

c) Element (b) of Claim 27, "at least one bcc-d layer which is magnetic," is met by the [redacted] Products

282. Element (b) of claim 27 provides "at least one bcc-d layer which is magnetic."

283. Element (b) is literally met by the [redacted] Products. Specifically, the [redacted] products include at least one bcc-d layer which is magnetic, for all of the reasons listed in Section VI.1.c. above. Thus, it is my opinion that element (b) of claim 27 is met by the [redacted] Products.

d) Element (c) of Claim 27, "forming a uniaxial symmetry broken structure," is met by the [redacted] Products

284. Element (c) of claim 27 provides "forming a uniaxial symmetry broken structure."

285. Element (c) is literally met by the [redacted] Products. Specifically, the [redacted] products include at least one bcc-d layer which is magnetic and forms a uniaxial symmetry broken structure, for all of the reasons listed in Section VI.1.d. above. Thus, it is my opinion that element (c) of claim 27 is met by the [redacted] Products.

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e) Alternatively, the "uniaxial" limitation is met by the [redacted] Products pursuant to the doctrine of equivalents

286. Alternatively, it is my opinion that the [redacted] Products infringe claim 27 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents and, as I have explained, all of the other limitations of claim 27 of the '988 patent are literally present in the [redacted] Products. Based on all of the information discussed in Section VI.1.e, it is my opinion that, to the extent the "uniaxial" limitation is not literally satisfied by the [redacted] Products, this limitation is met pursuant to the doctrine of equivalents. Accordingly, claim 27 of the '988 patent is infringed by the [redacted] Products under the doctrine of equivalents.

f) Element (d) of Claim 27, "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer," is met by the [redacted] Products

287. Element (d) of claim 27 provides "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer."

288. Element (d) is literally met by the [redacted] Products. Specifically, the [redacted] products include at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer, for all of the reasons listed in Section VI.1.f. above. Thus, it is my opinion that element (d) of claim 27 is met by the [redacted] Products.

9. Opinion No. 23: The [redacted] Products Infringe Claim 28 of the '988 Patent

a) Claim 28, "[t]he magnetic device recited in claim 27, wherein the device is a magnetic data storage system," is met by the [redacted] Products

289. Claim 28 of the '988 patent provides "[t]he magnetic device recited in claim 27, wherein the device is a magnetic data storage system."

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290. [redacted]

10. Opinion No. 24: The [redacted] Products Infringe Claim 29 of the '988 Patent

a) Claim 29, "[t]he magnetic device recited in claim 27, wherein the device is a data storage magnetic recording transducer," is met by the [redacted] Products

291. Claim 29 of the '988 patent provides "[t]he magnetic device recited in claim 27, wherein the device is a data storage magnetic recording transducer."

292. [redacted]

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11. Opinion No. 25: The [redacted] Products Infringe Claim 1 of the '988 Patent

293. It is my opinion that the [redacted] Products infringe claim 1 of the '988 patent. It is my opinion that every element of claim 1 is literally met by each of the [redacted] Products. I explain the foundation for my opinion on an element-by-element basis below. Alternatively, it is my opinion that the [redacted] Products inbrafringe claim 1 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents. Accordingly, claim 1 is infringed by the [redacted] Products where "uniaxial" is met pursuant to the doctrine of equivalents and all other limitations are literally present.

294. I understand that the Court construed certain terms in claim 1 of the '988 patent. Specifically, I understand that the Court construed six terms from the claims of the '988 patent as reflected in the table below.

Term	Construction
"atomic template"	An atomic pattern upon which material is grown and which is used to direct the growth of an overlying layer
"[Layer] providing a (111) textured hexagonal atomic template"	Layer that is predominately (111) hexagonal and that provides an atomic template
"Uniaxial"	Having an anisotropy energy density function with only a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis
"Symmetry broken structure"	A structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system
"Uniaxial symmetry broken structure"	A structure that is uniaxial as a result of the structure being symmetry broken
"Variant/orientational variant" "Variants/orientational variants"	One of a set of possible crystal orientations Two or more of a set of possible crystal orientations
"bcc-d"	Either a body centered cubic or a body centered cubic derivative crystal structure
"fcc-d"	Either a face centered cubic or a face centered cubic derivative crystal structure

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See Claim Construction Order, at 7-8. I have applied the Court's constructions for all construed terms in my infringement analysis. I have applied the plain and ordinary meaning according to a person having ordinary skill in the art to all non-construed terms.

a) To the extent the preamble to claim 1, "[a] magnetic material structure comprising" is limiting, it is met by the [redacted] Products

295. The preamble to claim 1 recites "[a] magnetic material structure comprising."

296. I understand that the preamble to a patent claim is generally not limiting. I further understand that Seagate has not sought construction of the preamble to claim 1 of the '988 patent and has not asserted that it is limiting, nor has the Court construed the preamble of claim 1 of the '988 patent to be limiting. Nevertheless, each of the [redacted] Products include a magnetic material structure.

297. [redacted]

298. [redacted]

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[redacted]

299. Reverse engineering performed at my direction on a representative [redacted] Product, specifically a hard disk drive bearing Seagate model no. ST500DM002-1BD142 500 GB and referred to as sample SBRD8K, shows that the [redacted] Products include a magnetic material structure in the write pole. [redacted] An image of [redacted] Product sample SBRD8K before it was torn down is shown below.

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Seagate Barracuda 500 GB Hard Drive
ST500DM002 (SBRD8K)

300. To access the magnetic material structure, the top of the [redacted] was removed so that a view of the drive interior is visible and accessible, as shown below for sample SBRD8K.

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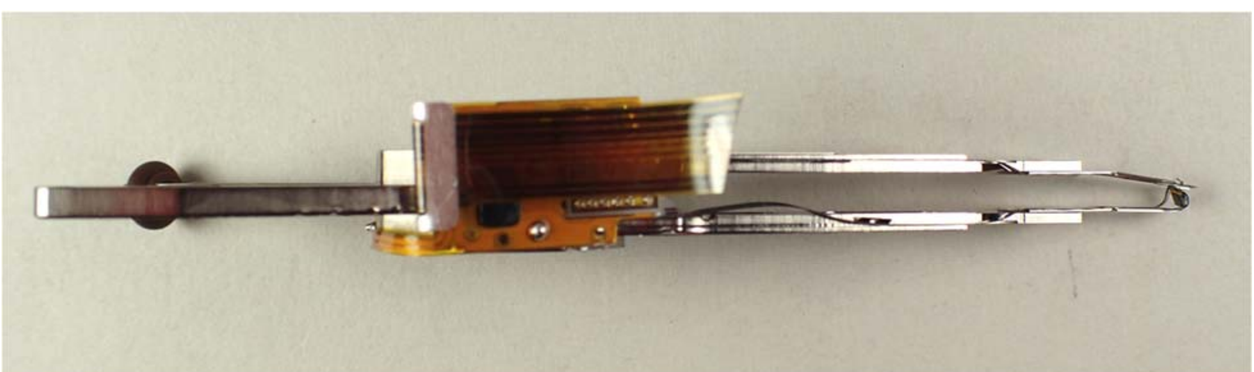
Seagate Barracuda 500 GB Hard Drive
ST500DM002 (SBRD8K)

301. After the top of the [redacted] Product was taken off, then the actuator arm with head gimbal assemblies was removed, and is shown in the first image below from sample SBRD8K. A zoomed in image of the HGAs from sample SBRD8K is also shown in the second image below.



Seagate Barracuda 500 GB Hard Drive
ST500DM002 (SBRD8K)

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302. Next, a FEI 200 TEM FIB using a gallium focused ion beam was used to take an image of the heads at the tip of an HGA. Specifically, an image of the slider containing the heads in sample SBRD8K is shown below. A region of this slider was then removed by the in-situ lift out technique to provide a cross-section for analysis of the [redacted] write pole material. This technique and steps were performed as described above in Section VI.1.a.

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303. SEM imaging in the Zeiss Crossbeam 1540 XB was used to obtain a high-resolution image from this cross-section obtained from sample [redacted]. The Zeiss Crossbeam instrument was also used to further thin the sample for enhanced electron transparency. It is possible to observe several features of the slider. For instance, in the backscatter 1 kV image below, the coils and the main write pole (including iron cobalt layers extending to the ABS) are shown on the left side of the image below for sample [redacted] The read head is also visible on the right side of the image below. Further to the left and right of the heads, the lower and upper shields are visible.

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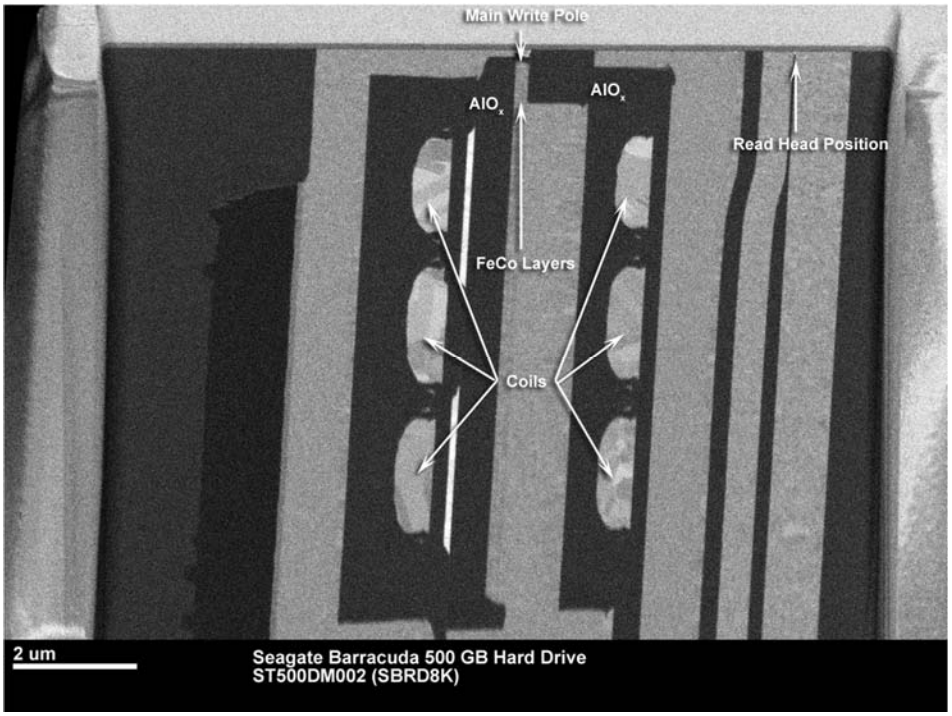

304. Analyzing the SBRD8K sample in a TEM Tecnai F30 operated at 300 kV in brightfield mode, one can observe the magnetic material structure meeting the limitations of claim 1 of the '988 patent is in the write head. This magnetic material structure can be observed using TEM to inspect the FIB-prepared cross-section sample at higher magnification. Note that the AlTiC substrate of the magnetic material structure of claim 1, is not observable in many images illustrating the material layers in the write pole due to the high level of magnification necessary to show on the FeCo, Ru and NiFe layers.

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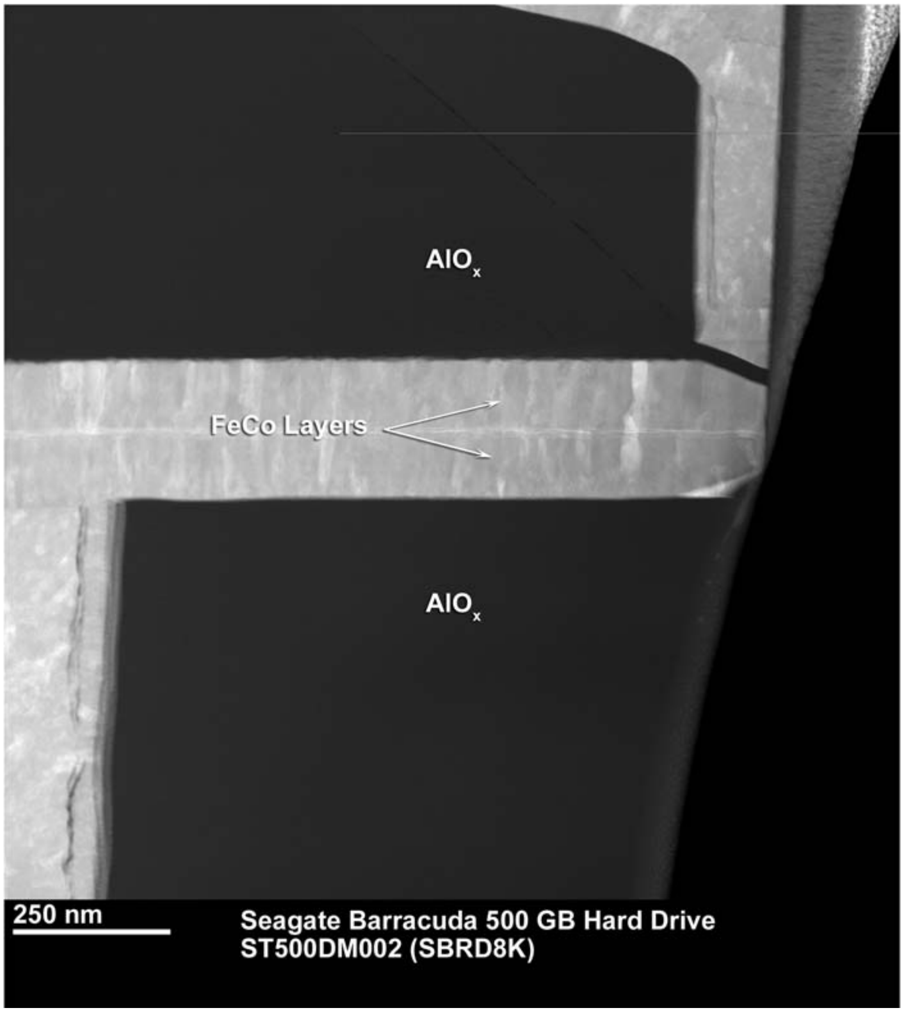

305. In the claimed magnetic material structure, both the FeCo and the NiFe layers are magnetic. The growth direction is of the layers shown in the image above is from the bottom of the image to the top.

306. I understand that further TEM imaging at high resolution was performed on the cross-section of the write head prepared sample SBRD8K as described in Dr. Clark's report. *See* Clark Report at Sections E.2. and F.2.a.2. These additional TEM images of a cross-section of a [redacted] Product illustrate layers in the write head that are part of the claimed magnetic material structure, including magnetic material layers of FeCo and NiFe. *See id*. at Section

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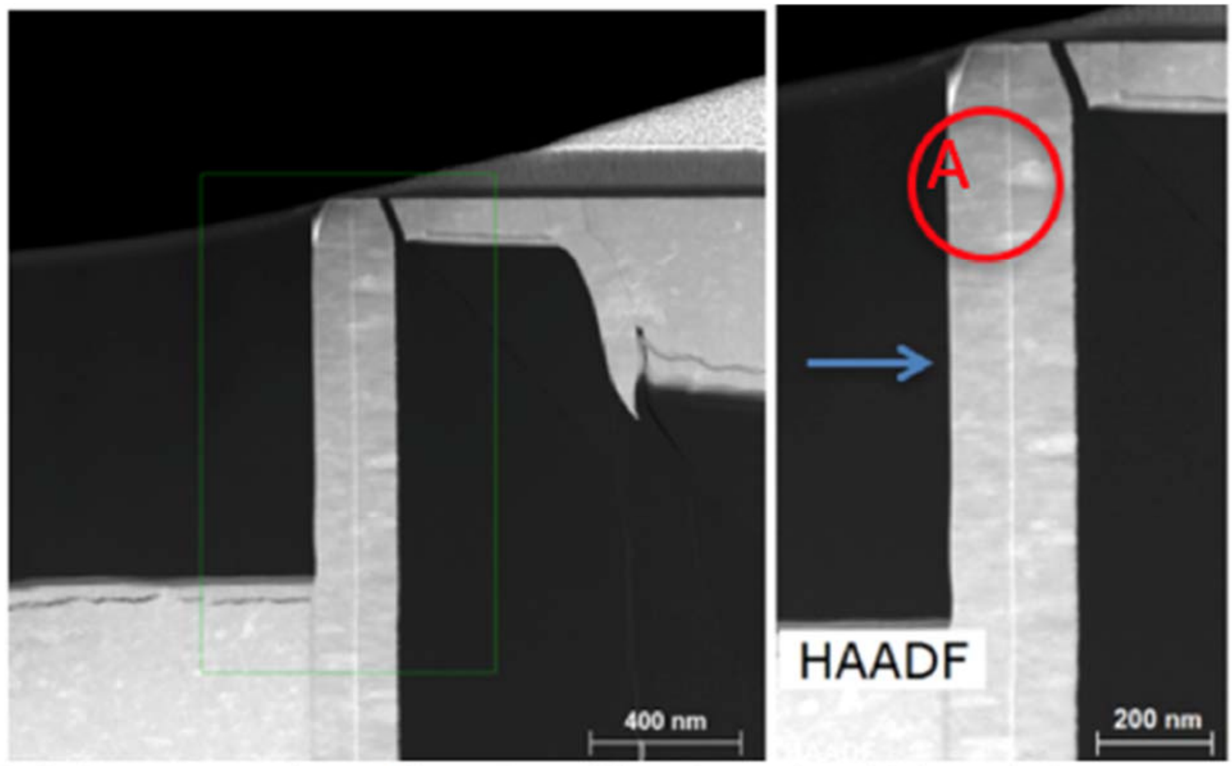
F.2.a.2. In the TEM image below reproduced from Dr. Clark's Report, the magnetic layers are observable and the growth direction annotated.



307. I further understand that composition of the magnetic material layers in the write head for [redacted] Products was further confirmed by using energy dispersive x-ray spectroscopy ("EDS"), as described in Dr. Clark's report. *See* Clark Report at Sections E.3 and F.2.a.1. From the EDS imaging of sample SBRD8K shown below, magnetic layers of the write head that are part of the claimed magnetic material structure can be observed, specifically the FeCo, Ru, and NiFe layers, as shown below. Here again, the growth direction for the layers is from the top of the image towards the bottom.

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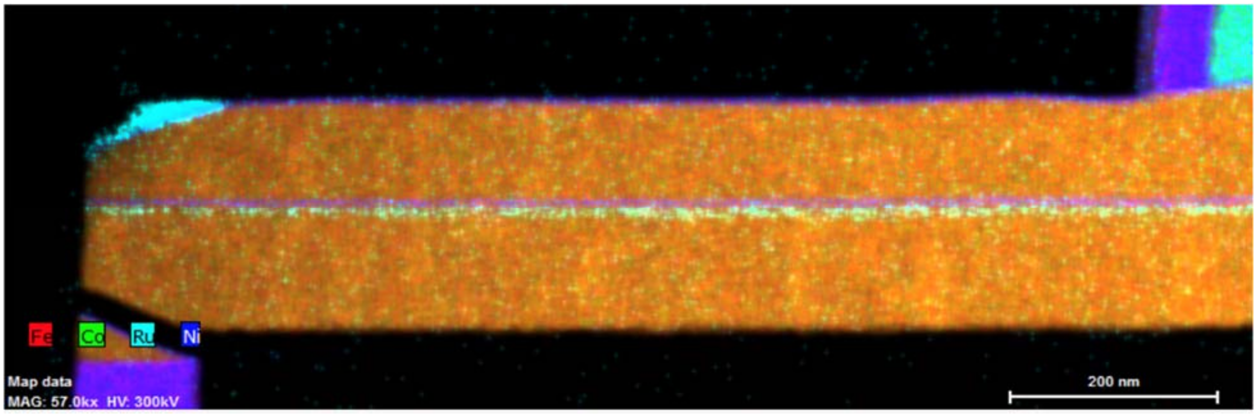

308. [redacted]

309. In consideration of all of the evidence described above, it is my opinion that the [redacted] Products include a magnetic material structure including, at least, an AlTiC wafer material, and at least one layer of NiFe material and at least one layer of FeCo material within the write pole.

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310. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers in the write pole of the [redacted] Products meet the preamble, to the extent it is limiting.

311. Thus, it is my opinion that, to the extent the preamble to claim 1 is limiting, it is met by the [redacted] Products.

b) Element (a) of Claim 1, "a substrate," is met by the [redacted] Products

312. Element (a) of claim 1 of the '988 patent provides "a substrate."

313. [redacted]

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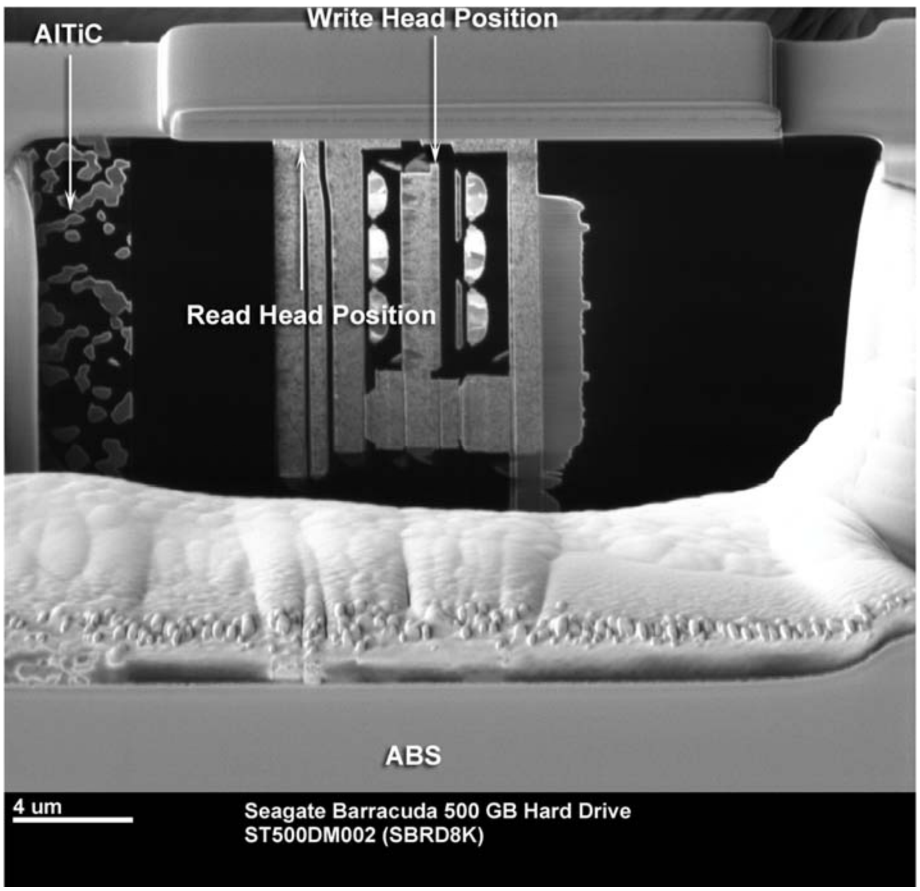
314. I also confirmed the presence of the AlTiC wafer substrate below the write pole in the [redacted] Products by analyzing a cross-section from a representative [redacted] Product, specifically sample SBRD8K via imaging in a FEI 200 TEM FIB gallium focused ion beam ("FIB") system during lift out of a cross-section sample. The process of preparing the cross-section sample is discussed in detail above in Section VI.1.a. In the image below, the AlTiC wafer substrate is visible on the left of the image and the material layers comprising the head, including the write pole, deposited on top of the AlTiC wafer substrate are visible to the right.



315. [redacted]

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316. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers in the write pole of the [redacted] Products meet this limitation.

317. Therefore, for at least the reasons described above, the [redacted] Products include a substrate, which is an AlTiC wafer. Thus, it is my opinion that element (a) of claim 1 of the '988 patent is met by the [redacted] Products.

c) Element (b) of Claim 1, "at least one bcc-d layer which is magnetic," is met by the [redacted] Products

318. Element (b) of claim 1 of the '988 patent provides "at least one bcc-d layer which is magnetic."

319. [redacted]

320. [redacted]

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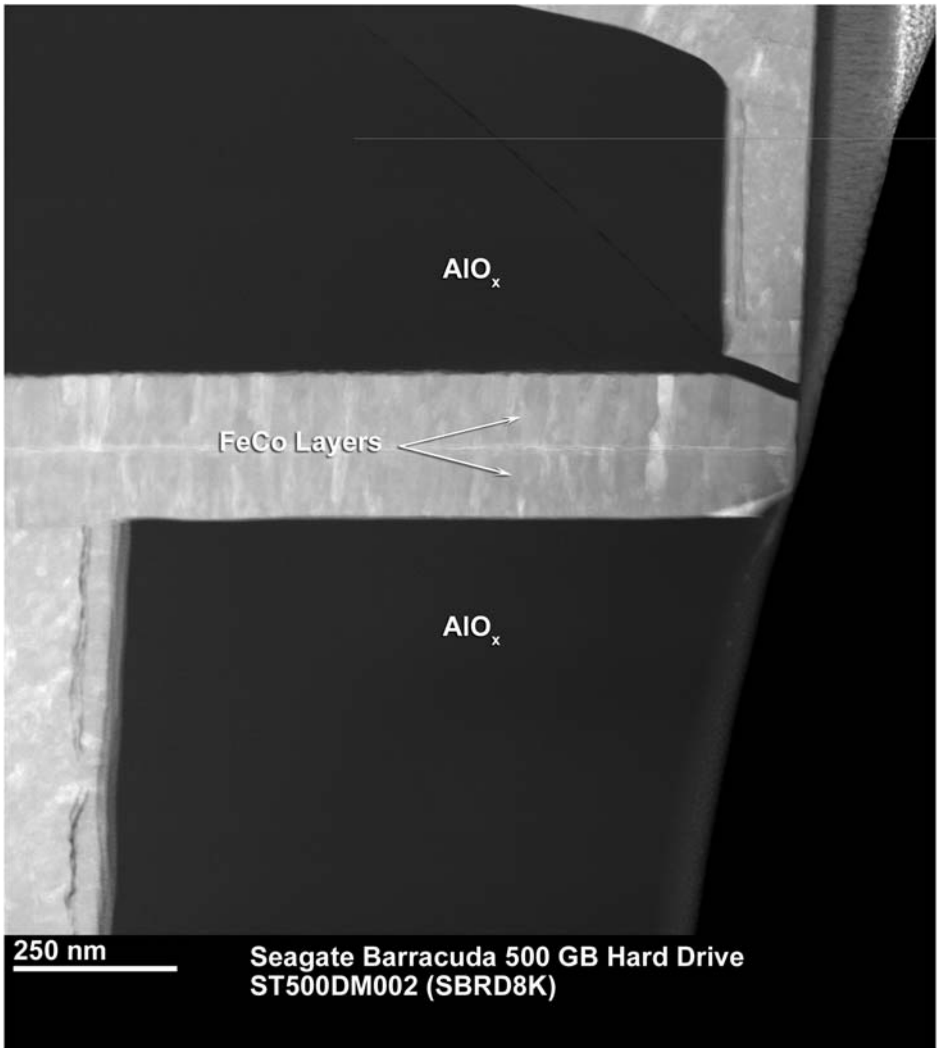
[redacted].



321. I also confirmed the presence of the three FeCo layers in the [redacted] write pole, including the lower layer, in the EDS analysis shown below. I understand that this image was taken in a TEM on the same cross-section of sample SBRD8K a representative [redacted] Product, discussed at Section VI.1.a. above and confirms the composition of the layers shown, including the lower FeCo layer that is the magnetic bcc layer on which I am basing my

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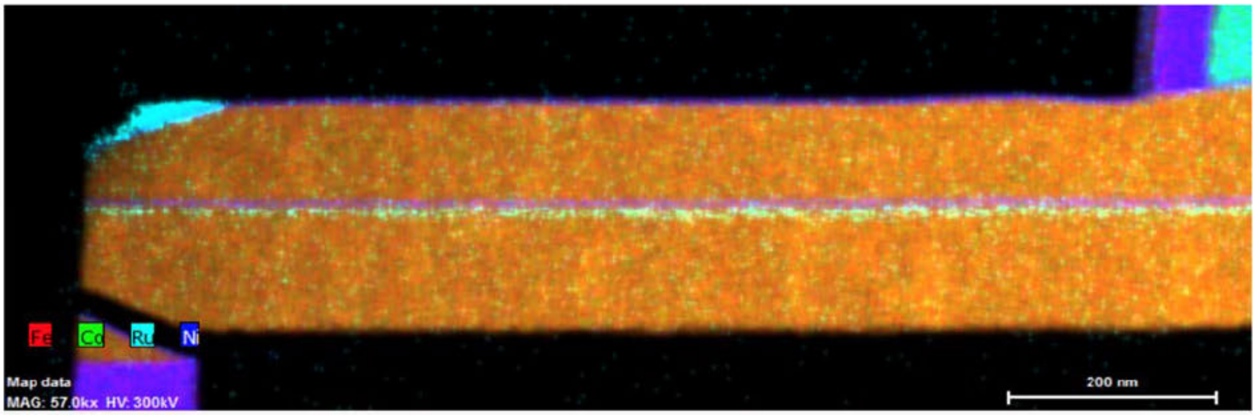
infringement opinion with respect to claim 1 of the ‘988 patent. *See* Clark Report at Section F.2.a.1.



322. I understand that analysis of a series of FFTs performed on a high resolution TEM image in the area of the lower FeCo layer of a representative [redacted] Product, sample SBRD8K in the area where lattice fringes are observed shows that the lower FeCo layer has a bcc crystal structure. *See* Clark Report at Sections E.2.i and F.2.a.3. Dr. Clark created and analyzed a series of FFTs from across the sample at the interfaces between NiFe and FeCo layers and the interfaces between Ru and FeCo.

323. I understand that Dr. Clark’s analysis of FFTs led him to conclude that the lower FeCo layer in a representative [redacted] Product has a bcc crystal structure. *See* Clark Report at Section F.2.a.3.

324. A plan view sample from a head from representative [redacted] Product sample SBDR8K was further prepared via the in-situ lift out technique as described in Section VI.1.c. to provide a sample comprising the lower FeCo and NiFe layers of the write pole material in THE [redacted] Products. *See, e.g.*, Giannuzzi, L.A. Kempshall, B.W., et al., INTRODUCTION TO FOCUSED ION BEAMS: INSTRUMENTATION, THEORY, TECHNIQUES AND PRACTICE, “FIB Lift-out Specimen Preparation Techniques: Ex-Situ and In-Situ Methods,” Lucille A. Giannuzzi, eds.

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(2005); Kempshall, B.W. and L.A. Giannuzzi, "In-Situ Lift-Out FIB Specimen Preparation for TEM of Magnetic Materials," *Microsc. Microanal.*, 8 (Suppl. 2), 2002, 590-91; Giannuzzi, Lucille A., Brian W. Kempshall, et al., "FIB Lift-Out for Defect Analysis," *Microelectronic Failure Analysis Desk Reference 2002 Supplement*, 29-35; Kempshall, B.W., et al., "A microstructural observation of near-failure thermal barrier coating: a study by photostimulated luminescence spectroscopy and transmission electron microscopy," *Thin Solid Films*, 466 (2004) 128-136.

325. Additionally, I understand that analysis of microbeam diffraction data collected from plan view sample SBDR8K, which is a representative [redacted] Product, confirms that the lower FeCo layer in the [redacted] Products have a bcc crystal structure and a (110) crystal texture. *See* Clark Report at Sections E.2.d. and F.2.b.4.

326. [redacted]

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[redacted].

327. [redacted]

328. [redacted]

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[redacted]

329. [redacted]

330. [redacted]

331. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers, as well as the Ru layer and overlying FeCo layer, in the write pole of the [redacted] Products meet this limitation.

332. Therefore, for at least the reasons described above, the [redacted] Products comprise at least one bcc-d layer which is magnetic. Thus, it is my opinion that element (b) of claim 1 of the '988 patent is met by the [redacted] Products.

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d) Element (c) of Claim 1, "forming a uniaxial symmetry broken structure," is met by the [redacted] Products

333. Element (c) of claim 1 of the '988 patent provides "forming a uniaxial symmetry broken structure."

334. Element (c) is literally met by the [redacted] Products. Specifically, the [redacted] Products all contain a lower layer of FeCo material in the write pole that includes multiple polycrystalline grains of (110) textured bcc FeCo. The grains of (110) bcc FeCo in the lower layer of FeCo material in the write pole of the [redacted] Products are oriented relative to the (111) hexagonal template provided by the NiFe template layer directly beneath them such that the lower FeCo layer consists of variants from the six variant Kurdjumov-Sachs system. As discussed further below and in Dr. Clark's report, the lower layer of FeCo material in the [redacted] Products' write poles has unequal amounts of the bcc variants in the Kurdjumov-Sachs six variant system and, accordingly, is symmetry broken according to the Court's construction of the term "symmetry broken." Furthermore, as discussed further below and in Dr. Clark's report, the result of the symmetry breaking in the lower layer of FeCo in the [redacted] Products' write poles is uniaxial anisotropy in the measured region of that material layer. Specifically, the unequal amounts of variants in the six variant system observed by dark field image analysis at different angles rotated by 180 degrees from a physical axis were measured and the resulting anisotropy energy density function was calculated. As discussed in further detail below, it is my opinion that the lower layer of FeCo in the [redacted] Products is uniaxial because the anisotropy energy density function I calculated solely due to the measured broken symmetry in representative samples of the [redacted] Products has a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis.

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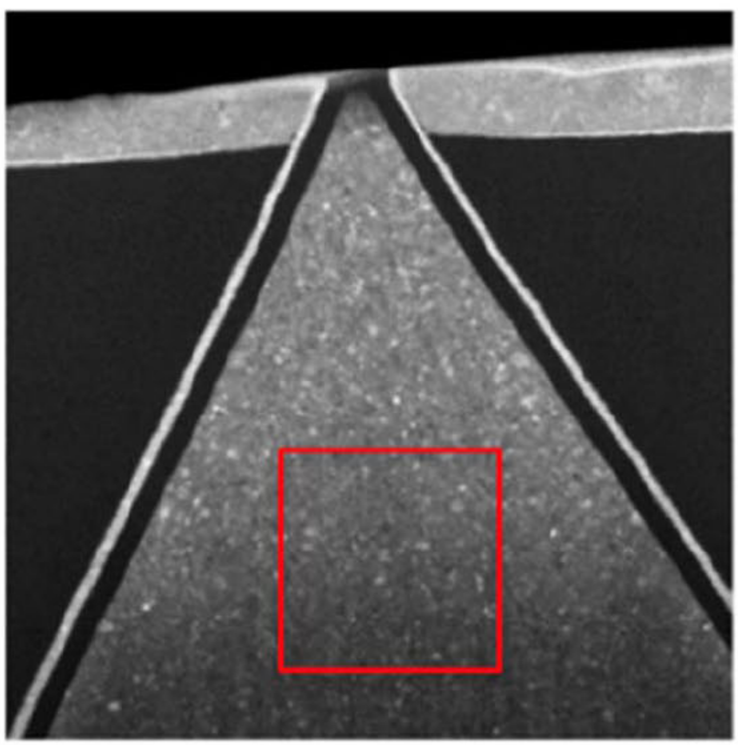
335. The lattice parameters of the bcc FeCo magnetic layers and fcc NiFe hexagonal template layers used by Seagate for the [redacted] head are reasonably well known (Bozorth at 104, 192; Singh et al, J. Mag. & Mag. Mat., v 324, p 999, 2012) and from these the ratios of fcc to bcc nearest neighbor distances can be calculated and are within the range of 1.04 to 1.01. For this range, the six variant Kurdjumov-Sachs orientation relationship is favored over the 3 variant Nishiyama-Wasserman orientations, and this six variant system is what is experimentally observed for the [redacted] Product sample, SBRD8K.

336. I understand that microbeam diffraction analysis of a representative sample of the [redacted] Products shows that the lower layer of FeCo in the write pole contains multiple (110) bcc crystalline grains that are members of the Kurdjumov-Sachs six variant system. *See* Clark Report at Sections E.2.d. and F.2.a.4. I understand that Dr. Clark performed microbeam diffraction analysis on the area of a plan view sample from sample SBRD8K as indicated by the red annotation on the TEM image below, which is reproduced from Dr. Clark's report. *See id.*



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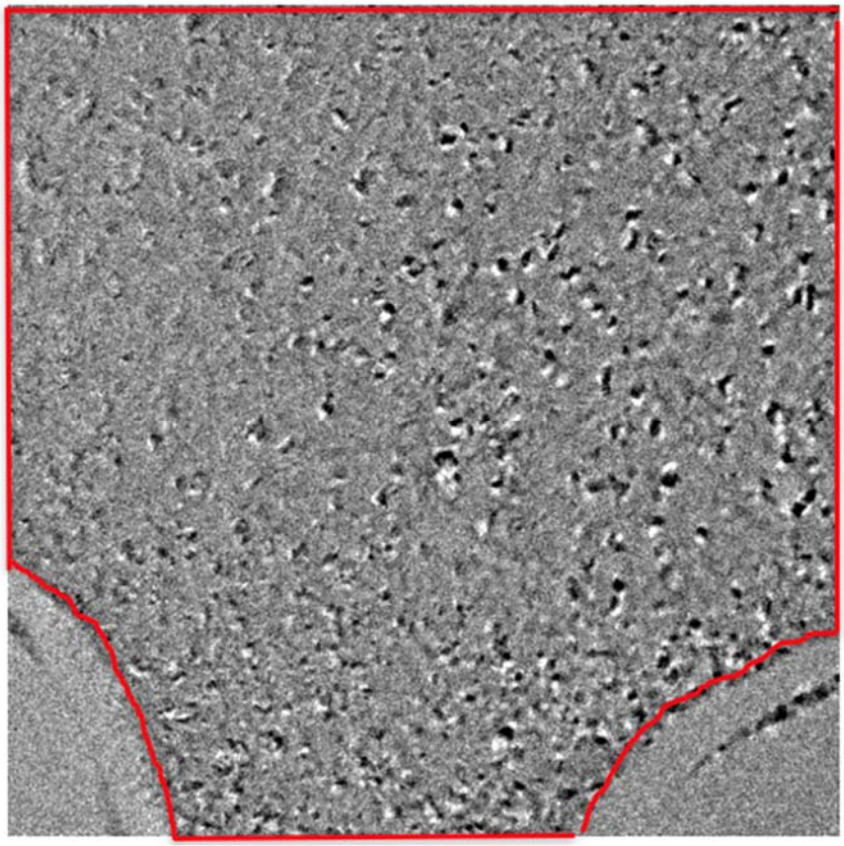
337. I further understand that there are unequal amounts of variants from the Kurdjumov-Sachs six-variant system in the lower layer of FeCo in sample SBRD8K based on high resolution cross-sectional imaging. *See id*. at Section F.2.a.3. Dr. Clark used FFTs to analyze a cross-section sample from sample SBRD8K to confirm that the FeCo grains in the lower layer of FeCo and the lower layer of NiFe have an epitaxial $(111)_{NiFe}||(110)_{FeCo}$ orientation relationship with the in-plane directions $<111>_{bcc}||<110>_{fcc}$, which confirms that the FeCo grains are composed of variants from the Kurdjumov-Sachs six-variant system. *See id*. As discussed above, sample SBRD8K is representative of the [redacted] Products (*see* Section VII.1.a.) and, accordingly, I conclude that each of the [redacted] Products has a lower layer of FeCo that forms a symmetry broken structure.

338. I further understand from Dr. Clark's report that the in-plane dimensions of the bcc crystals of the FeCo layer are comparable to the in-plane dimensions of the crystals in the NiFe hexagonal template layer with which they have a six-variant Kurdjumov-Sachs relationship. *See* Clark Report at Section F.2.a.3; *see also id*. at Section F.2.a.5. Accordingly, it is unlikely for there to be more than two such bcc variants on a single template crystal, and it is extremely unlikely to have all six variants on a single template crystal. *See id*. It is even more unlikely to have equal amounts of all six variants on a single template crystal. *See id*. Accordingly, this structure literally meets the Court's construction of "symmetry broken" as it is a structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system.

339. I also understand that dark field image analysis of sample SBRD8K shows symmetry breaking in the lower layer of FeCo in the write pole. *See* Clark Report at Sections E.2.f. and F.2.a.5. I understand that Dr. Clark performed a dark field imaging analysis on the

area of a plan view sample from sample SBRD8K as indicated by the red annotation on the TEM image below, which is reproduced from Dr. Clark's report. *See id*. at Section F.2.a.5.



340. I further understand that this dark field analysis determined the relative area fractions of crystallites having aligned <100> directions as a function of the measurement angle in the plane at 10 degree intervals rotated 180 degrees from a physical axis for sample SBRD8K. *See* Clark Report at Sections F.2.a.5. I understand that this dark field imaging analysis provides information on the fraction of crystallites with their easy axes substantially aligned toward each measured orientation and, consequently, shows the presence of unequal amounts of variants in the Kurdjumov-Sachs six-variant system because a greater amount of bcc-d crystallites are composed of variants with their easy axis aligned substantially perpendicular to the long axis of the write head (parallel to the ABS) than in other directions. *See id*. As discussed above, sample

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SBRD8K is representative of the [redacted] Products (*see* Section VII.1.a.) and, accordingly, dark field analysis supports my conclusion that each of the [redacted] Products has a lower layer of FeCo that forms a symmetry broken structure.

341. Using the results of Dr. Clark's dark field imaging analysis on [redacted] Product sample SBRD8K, I performed further analysis to determine that the lower FeCo layer in the write pole of [redacted] Products has an anisotropy energy density function with only a single maximum and a single minimum as the magnetization is rotated by 180 degrees from a physical axis due solely to the anisotropy resulting from the presence of unequal amounts of the bcc-d variants of a six variant system in the lower FeCo layer. That is, it is my opinion that the lower FeCo layer in the [redacted] Products is uniaxial as a result of the structure therein being symmetry broken, in accordance with the Court's construction of claim 1 of the '988 patent.

342. My analysis to determine that the lower FeCo layer is uniaxial as a result of the structure therein being symmetry broken utilized Dr. Clark's dark field imaging analysis. I understand that Dr. Clark's dark field imaging analysis of [redacted] Product sample SBRD8K determined the relative area fractions of crystallites having aligned <100> directions in the film plane as a function of the measurement angle in the plane. *See* Clark Report at Section F.2.a.5. Dr. Clark made such measurements at 10 degree intervals in a rotation of 180 degrees or more from a physical axis. Dr. Clark's raw data, as it was provided to me, is presented in Appendix H. The symmetry of the bcc crystal structure is such that crystals having a <100> direction in the plane aligned at 80 degrees will necessarily also have a <100> direction in the plane aligned at 80 + 180 = 260 degrees, and this is the case for all data provided by Dr. Clark. Accordingly, I used this crystal symmetry to extend the range of data to of 360 degrees (a full circle), allowing the variation in area percentage with angle to be evident. When more than one experimental

value for the area fraction was available at orientations 180 degrees apart, these values were averaged to be consistent with crystal symmetry and reduce the experimental variation of the data. The area fraction data was then normalized over the range of 0 to 360 degrees to provide a sum total area of 100%. This in-plane orientation data of the (110) textured bcc FeCo crystallites had a systematic sinusoidal variation in area fraction as a function of angle from a physical axis. In addition to the sinusoidal variation, small random deviations from the sinusoidal variation were present. To identify the magnitude of the sinusoidal variation the data for each sample was modeled by the equation:

$$Area\ Fraction = A(\sin(\Theta + \Delta))^2 + B(\cos(\Theta + \Delta))^2$$

The values of A, B and □ were chosen to minimize the sum of the squared differences between the equation and experimental values at each angle, □, where the normalized experimental values were available (least squared fitting). The figure below is a plot of the normalized experimental data (as points) along with a solid line calculated with the equation above for the SBRD8K sample. *See* Appendix H.

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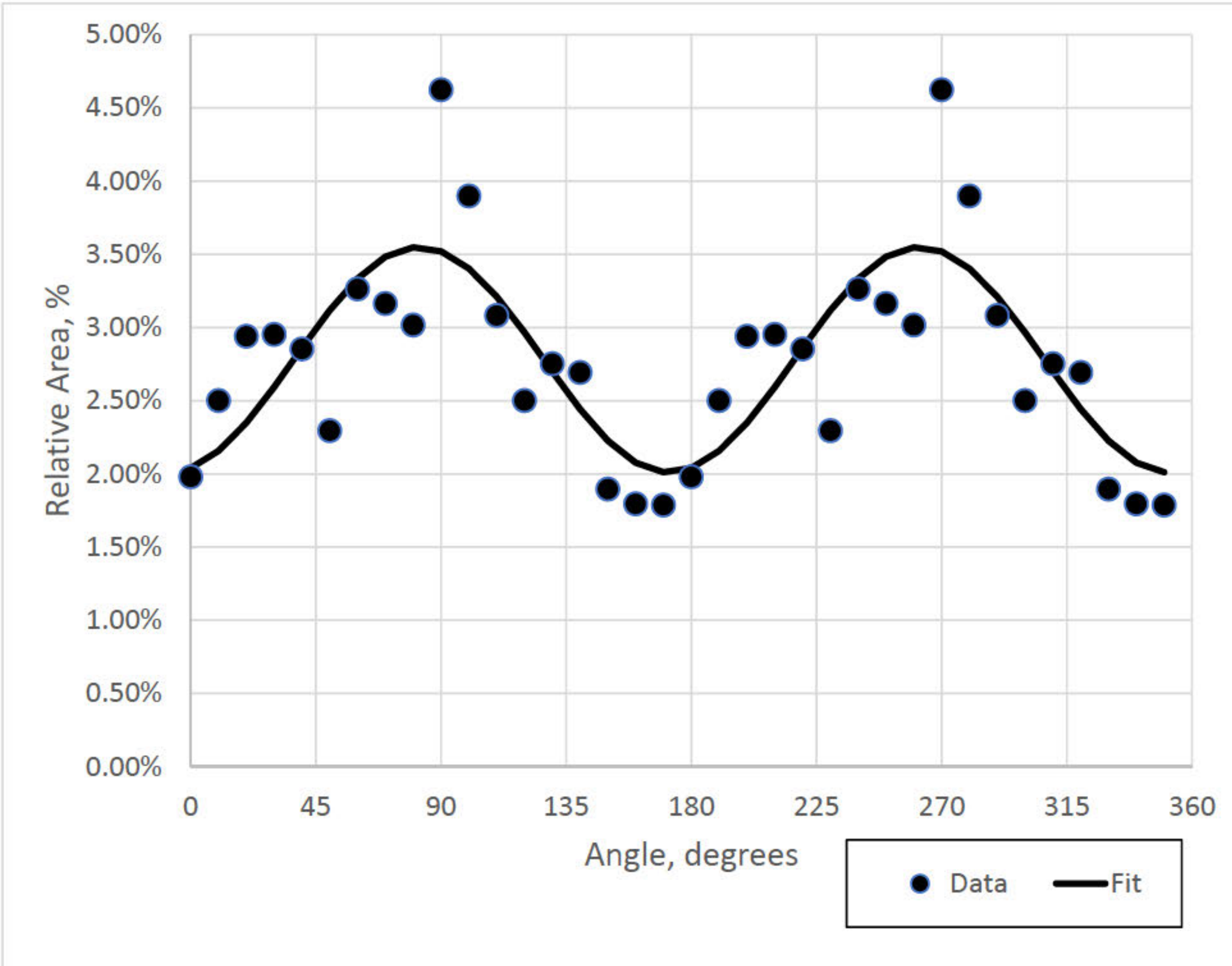

The area fraction for the (110) bcc, six-variant crystallites is not independent of direction, rather it shows a pronounced variation as a function of angle. Accordingly, not all variants are equally present and the SBRD8K sample has broken symmetry. For this sample, the orientation at zero degrees was chosen to be perpendicular to the ABS, and peak in area fraction near 90 and 270 degrees is understood as being perpendicular to the ABS.

343. It is well known in the literature that all bcc-d crystals have a smooth anisotropy energy density function in the (110) plane. Indeed, the anisotropy energy density function for bcc-d crystals in the (110) plane is set forth in Chikazumi and referenced in the '988 patent. *See*

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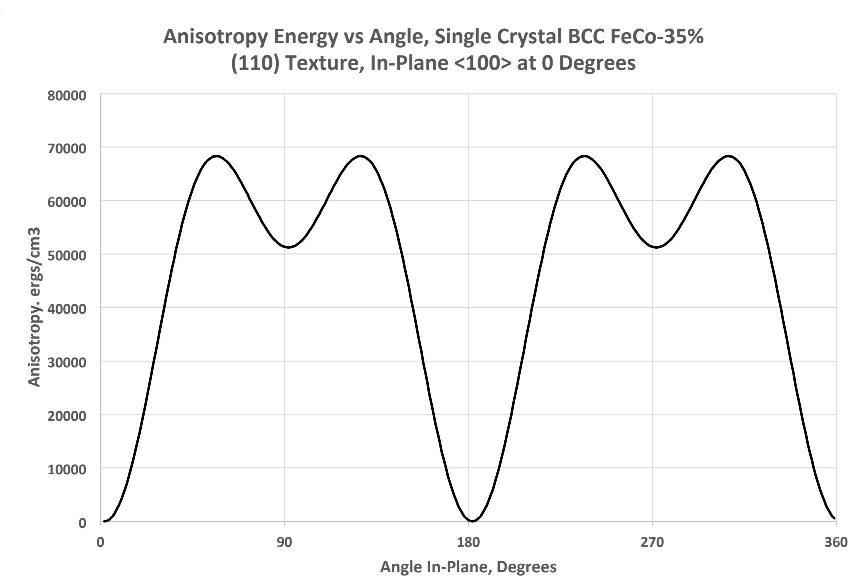
Soshin Chikazumi, PHYSICS OF FERROMAGNETISM (1997) ("Chikazumi") at 259-266; '988 patent at col. 11, ll. 30-58, and Figure 4). Specifically, the equation is:

$$E_{110}(\theta) = K_1\{(^1/_4)sin^4(\theta) + \sin^2(\theta)\cos^2(\theta)\} + K_2\{(^1/_4)\sin^4(\theta)\cos^2(\theta)\}$$
$$+ \text{ higher } K \text{ terms}$$

344. To illustrate that this anisotropy energy density function for the (110) plane of bcc-d crystals is a smooth function, I have plotted the function below. (Note that for this chart, as for the [redacted] Products, K_2 and higher terms are negligible.) *See* Appendix D.



345. In the '988 patent, Dr. Lambeth calculated the anisotropy energy density function associated with combinations of variants in a bcc-d magnetic layer on a single crystal template. *See, e.g.*, '988 patent at 18:46-23:15. Here, the Hybrid_X Products have a polycrystalline NiFe template layer beneath the lower FeCo layer that is a bcc-d magnetic layers. Accordingly, to determine the overall anisotropy energy density due to the symmetry breaking evidenced in the

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lower FeCo layer in the Hybrid_X Products it is necessary to calculate the anisotropy energy density as an average over all of the crystallites at different orientations in the sample..

346. The averaging of the anisotropy energy of individual crystals to determine an effective average anisotropy energy for a polycrystalline sample is described by G. Herzer, "Grain size dependence of coercivity and permeability in nanocrystalline ferromagnets," *IEEE Trans. Magn.*, vol. 26, no. 5, pp. 1397-1402, Sept. 1990 (produced by Seagate at SEA01974948). Herzer assumed that the orientations of the crystals in a sample was fully random (equal volumes present at all orientation angles). *See id*. at 1399-1400. For such a film, the average magnetocrystalline anisotropy energy would be constant as a function of angle and not display a maximum or a minimum. However, local statistical variations in the orientation of the crystals would result in small, but non-zero anisotropies in local regions that could pin domain walls and result in coercivity, and this local fluctuation would result in a local anisotropy that could be related to coercivity and grain size by the following equation:

$$H_c = p_c \frac{\langle K \rangle}{J_s} \approx p_c \frac{K_1^4 \cdot D^6}{J_s \cdot A^3} \qquad (5a)$$

See id. at 1400 (equation 5(a)). *See also* citations to Herzer in Mathieu et al., "Magnetic Anisotropy Dispersion in FeCo Films," *IEEE Trans. Magn.*, vol. 44, no. 4, Apr. 2008; Mathieu, et al., "Within wafer magnetic anisotropy in sputtered FeCo films," *J. App. Physics*, vol. 103, no. 07E715, 2008; SEA01134746 at 750; SEA00019292 at 307; SEA00027744 at 752; SEA00409798 at 607; SEA01134854 at 856; SEA01134932 at 934; SEA01941843 at 858; SEA01963227 at 233; SEA01986461 at 466; SEA01991054 at 069; SEA01991416 at 421; SEA01993371 at 376; SEA02033892 at 896; SEA02064462 at 470; SEA02066314 at 321;

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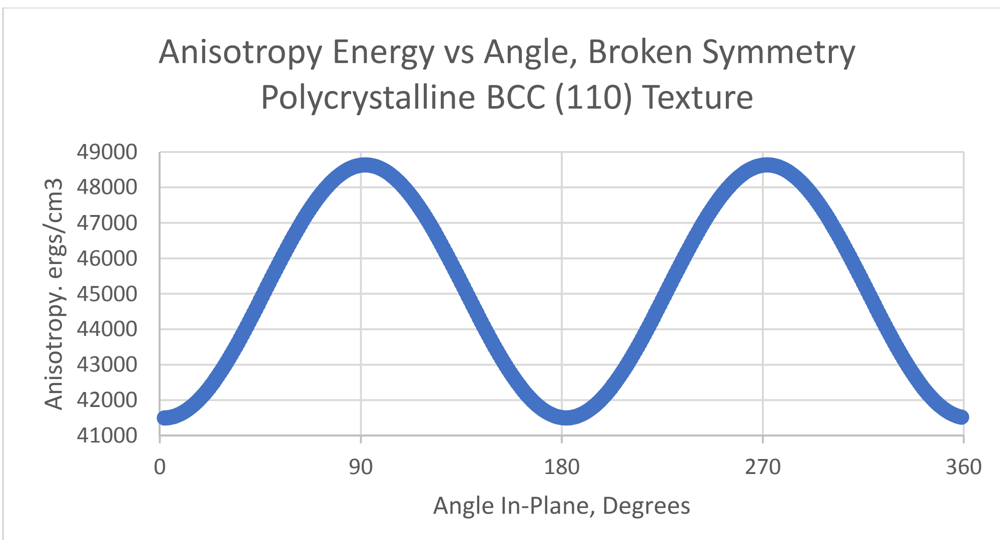
SEA02075274 at 276; SEA02078700 at 852; SEA02136396 at 401; SEA02303156 at 163; SEA02550841 at 847; SEA02588509 at 518.

347. I conclude that the [redacted] Products contain lower FeCo layers that are "uniaxial symmetry broken" under the Court's construction of that term and its constituent parts, "uniaxial" and "symmetry broken structure." I calculated the magnetocrystalline anisotropy energy density as a function of angle for the SBRD8K sample. The relative areas of crystals as a function of <100> orientation was calculated using the equation for the sinusoidal variation above and this was used to provide a weighted average of the magnetocrystalline energy density as a function of angle, averaging over 360 degrees of crystal orientation. The resulting average magnetocrystalline energy density as a function of angle for sample SBRD8K is shown below (*See* Appendix H):



Sample SBRD8K is representative of the [redacted] Products. For the calculation of these magnetocrystalline anisotropy energy density functions, I utilized a value for the anisotropy constant, K_1, as determined below.

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348. It is my opinion that this anisotropy energy density function is uniaxial under the Court's construction of the term "uniaxial" because it has a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis. Additionally, because this uniaxial anisotropy energy density function was determined solely by utilizing dark field imaging data that reflects the unequal amounts of the bcc-d variants of a six variant system, it is my opinion that the lower FeCo layers in the [redacted] Products are uniaxial as a result of being symmetry broken and, accordingly, meet the Court's construction of the term "uniaxial symmetry broken."

349. It is my opinion that the [redacted] Products include lower FeCo layers that are a uniaxial symmetry broken structure in accordance with the requirements of claim 1 of the '988 patent.

350. For the calculation of these magnetocrystalline anisotropy energy density functions, I utilized a value for the anisotropy constant, K_1, [redacted] I determined this value by averaging the two values provided by Hall in his published works *See* Hall 1959; Hall 1960. Also, I assumed, following the guidance of Hall, that a separate contribution from K_2 was not needed to describe the magnetocrystalline anisotropy of these alloys. As discussed in Hall 1959, anisotropy energy minima present in the <100> directions for a disk sample prepared with {110} faces is not sensitive to K_2. However, the anisotropy maxima in the (110) plane are known to be essentially additive in K_1 and K_2, although the K_2 contribution is weighted much more weakly. From this it is understood that Hall's experimental report of only a value for K_1 must necessarily include the contributions of both K_1 and K_2 (if not negligible) to the magnetocrystalline anisotropy energy maxima experimentally observed.

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351. To confirm that my calculations of the anisotropy energy density function based on dark field data collected from a sample [redacted] Product was correct, I considered carefully the appropriate value of the anisotropy constant, K_1, that I used, and the propriety of my assumption that K_2 is negligible in the case of FeCo [redacted]

352. The available values for the magnetocrystalline anisotropy constants for bcc FeCo alloys in the [redacted] are provided from the work of Hall. *See* Hall 1959; Hall 1960. Hall used a torque magnetometer designed by Byrnes for these measurements, and used single crystal samples formed as disks between (110) planes, hence these measurements are very appropriate for calculation of anisotropy energy density variation in the crystallographic (110) plane, as I have performed here. The instrument used by Hall provided a plot of torque as a function of angle on a strip chart recorder and was described by Hall as having a torque accuracy of 2%. *See* Hall 1958.

353. The figure below illustrates the torque curve expected for the measurement performed by Hall as a solid black line for a sample having the second anisotropy constant, K_2, equal to zero. Also shown are torque curves corresponding to large, non-zero values of K_2, equal to + K_1 and – K_1, as red dotted and blue dashed lines, respectively. For purposes of comparison of the three curves, they have been scaled to have the same maximum (near 27 and 205 degrees) and minimum values (near 154 and 334 degrees) of the torque amplitude. However, the minor maxima and minima are clearly different in the three cases, being 32% higher for the torque curve corresponding to $K_2 = K_1$ and 39% lower for the torque curve corresponding to $K_2 = -K_1$. Such large positive and negative values of K_2 result in torque differences that are more than 15

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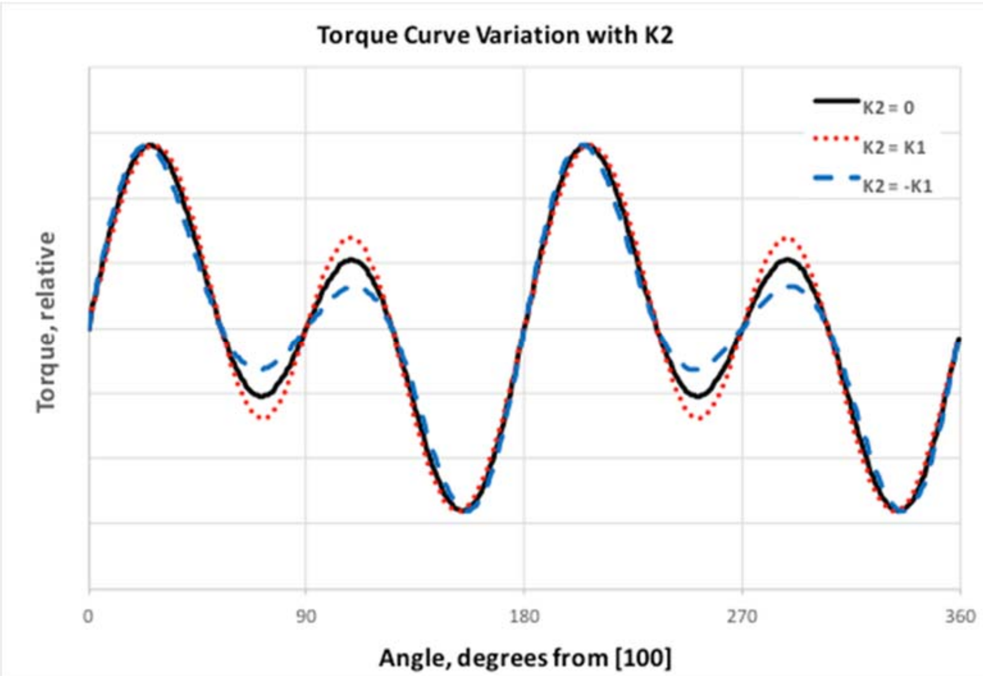
times greater the measurement accuracy and would certainly have been observed by Hall. My underlying calculations for preparing this figure are provided in Appendix E.



354. As Hall failed to report a value for K_2 from his experimental measurements, and he would have readily detected a relatively large value of K_2, we can conclude that such large K_2 values were not observed by Hall. Most likely, K_2 was positive or negative and near 10 % to 20% of K_1 in magnitude, as is reported for Fe and Fe-Al alloys. *See* Hall, R.C., "The Effect of the Order-Disorder Reaction on the Magnetic Anisotropy and Magnetostriction of Single Crystals of the Ferromagnetic Aluminum-Iron Alloys," *Trans. of the Metallurgial Soc. of AIME*, October 1958, 703-06 ("Hall 1958"). Our assumption that K_2 is negligible in comparison to K_1 to calculate the magnetocrystalline anisotropy energy density of FeCo alloys in the (110) plane is justified by Hall's choice to omit reports of K_2 in his publication of the K_1 values based on measurements made in the (110) plane of FeCo alloy samples. This is further supported by Hall's citation to Kouvel, wherein Kouval points out that small measurement errors in K_1 can appears as large relative changes for K_2. *See* Kouvel, J.S. and C.D. Graham, "On the Determination of

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Magnetocrystalline Anisotropy Constants from Torque Measurements," *J. of Applied Physics*, 28, 340-43 (1957). Accordingly, I concluded that my use of K_1 as calculated by Hall and determination that K_2 was negligible were proper.

355. [redacted]

356. [redacted]

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[redacted]

357. [redacted]

358. [redacted]

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[redacted]

359. [redacted]

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360. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers, as well as the Ru layer and overlying FeCo layer, in the write pole of the [redacted] Products meet this limitation.

361. As discussed above, it is my understanding that the lower layer of FeCo in the [redacted] Products forms a symmetry broken structure. Additionally, as my analysis of dark field imaging data obtained by Dr. Clark establishes, material in the lower layer of FeCo in the write pole of [redacted] Products is uniaxial as a result of the being symmetry broken and, accordingly, it is my opinion that the [redacted] Products include material that forms a uniaxial symmetry broken structure. Therefore, it is my opinion that element (c) of claim 1 of the '988 patent is literally met by the [redacted] Products.

e) Alternatively, the "uniaxial" limitation is met by the [redacted] Products pursuant to the doctrine of equivalents

362. Alternatively, it is my opinion that the [redacted] Products infringe claim 1 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents and, as I have explained above, all of the other limitations of claim 1 of the '988 patent are literally present in the [redacted] Products.

363. It is my opinion that the "uniaxial" limitation is infringed under the doctrine of equivalents because the [redacted] Products contain a lower FeCo layer that performs substantially the same function in substantially the same way to achieve substantially the same result as the claimed "uniaxial" limitation. I understand that Seagate may argue that, contrary to the Court's construction of "uniaxial," claim 1 requires that the bcc-d layer must exhibit uniaxial magnetic anisotropy due to symmetry breaking that dominates any other anisotropy that may be present or is the sole source of anisotropy in the bcc-d layer. While I disagree with this interpretation that adds a requirement to the Court's construction of "uniaxial," even if this

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interpretation were correct, evidence that I have provided in this Report shows that there are insubstantial differences between this interpretation of the requirements of the claims of the '988 patent and the attributes of the [redacted] Products.

364. Specifically, the function performed by "uniaxial" anisotropy is causing the bcc-d material to exhibit uniaxial magnetic properties. This function is being performed in the region of the lower FeCo layer in the [redacted] Products measured by dark field data analysis (*see* Section VII.1.d.) showing the measured region of the lower FeCo layer to be uniaxial due to symmetry breaking. Even if other anisotropies were present that enhanced or contradicted this measured intrinsic uniaxial anisotropy, the intrinsic uniaxial anisotropy caused by symmetry breaking performs substantially the same function of causing the bcc-d material to exhibit uniaxial magnetic properties.

365. Furthermore, the function of the "uniaxial" limitation is performed in substantially the same way regardless of whether other anisotropy is present—the contribution of uniaxial anisotropy due to symmetry breaking persists regardless of whether there are enhancing or contradicting anisotropies present, such as shape or stress anisotropy. This is supported by the dark field analysis which accounts solely for the uniaxial anisotropy due to symmetry breaking, regardless of any other anisotropies present. *See* Section VII.1.d. Thus, regardless of whether other anisotropies are present in the lower FeCo layer of the [redacted] Products, this intrinsic uniaxial anisotropy due to symmetry breaking (*i.e.*, breaking the symmetry of a six-variant system such that the symmetry breaking is a cause of the uniaxial magnetic behavior in the material) contributes towards the lower FeCo layer exhibiting substantially uniaxial magnetic properties in the region analyzed.

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366. Also, the result of this intrinsic uniaxial anisotropy due to symmetry breaking is substantially the same regardless of whether enhancing or contradicting sources of anisotropy are present in the lower FeCo layer. Even if other anisotropies are present, the intrinsic uniaxial anisotropy due to symmetry breaking substantially provides improved magnetic properties and a preferred magnetic orientation in the write pole. In sum, any differences between the magnetic anisotropy of the lower FeCo layer in the [redacted] Products and the claimed uniaxial material are insubstantial because the lower FeCo layer has intrinsic uniaxial anisotropy due to symmetry breaking in the lower FeCo layer. *See* Section VII.1.d. That the lower FeCo layer may have other contributors to its magnetic anisotropy, such as shape anisotropy or stress anisotropy, does not change the fact that the [redacted] Products achieve uniaxial magnetic properties as a result of symmetry breaking in the lower FeCo layer. As discussed above in Section VII.1.d., the presence of intrinsic uniaxial anisotropy in the lower FeCo layer due to symmetry breaking performs the desirable function of improving magnetic performance and mitigating undesirable attributes of a write pole material, such as Erase After Write.

367. A person having ordinary skill in the art would be aware that, for a magnetic thin film material, magnetic anisotropies are additive. Moreover, a person having ordinary skill in the art would be aware that shape anisotropy can be introduced by changing the shape of a magnetic thin film and, consequently, shape anisotropy may be introduced in a predictable manner without affecting the claimed anisotropy due to symmetry breaking. Similarly, a person having ordinary skill in the art would be aware of the possible addition of other types of anisotropy, such as stress anisotropy. As discussed in Section II.A., the '988 patent concerns the uniaxial magnetic anisotropy that results in a bcc-d material due to symmetry breaking. Therefore, so long as the bcc-d layer exhibits uniaxial anisotropy as a result of symmetry

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breaking, it meets claim 1 of the '988 patent and the presence of other types of anisotropy amount to an insubstantial difference.

368. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers, as well as the Ru layer and overlying FeCo layer, in the write pole of the [redacted] Products meet this limitation by the doctrine of equivalents.

369. Based on all of the information discussed above and in Section VII.1.d., it is my opinion that, to the extent the "uniaxial" limitation is not literally satisfied by the [redacted] Products, this limitation is met pursuant to the doctrine of equivalents. Accordingly, claim 1 of the '988 patent is infringed by the [redacted] Products under the doctrine of equivalents.

f) Element (d) of Claim 1, "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer," is met by the [redacted] Products

370. Element (d) of claim 1 of the '988 patent provides "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer."

371. Element (d) is literally met by the [redacted] Products. Specifically, the write pole of the [redacted] Products contains two layers of NiFe and one layer of Ru. The lower layer of NiFe serves as an atomic template because it provides an atomic pattern upon which the lower layer of FeCo is grown and directs this growth of the lower layer of FeCo. Moreover, as discussed further below, I understand that the lower layer of NiFe is predominately (111) hexagonal by virtue of having a fcc crystal structure and a predominantly (111) texture. The lower layer of NiFe is also disposed between the substrate (the AlTiC wafer material discussed in Section VII.1.b. above) and the bcc-d layer (the lower layer of FeCo, which has a (110) bcc crystal structure, as discussed in Section VII.1.c. above).

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372. [redacted]

[redacted]

[redacted]

373. [redacted]

374. [redacted]

375. As discussed above, I understand that the presence of the two NiFe layers in the write pole of the [redacted] Products has been confirmed by EDS analysis performed on representative sample SBRD8K. *See* Clark Report at Section F.2.a.1. The presence of both the lower and upper NiFe layers can be observed in the images below.

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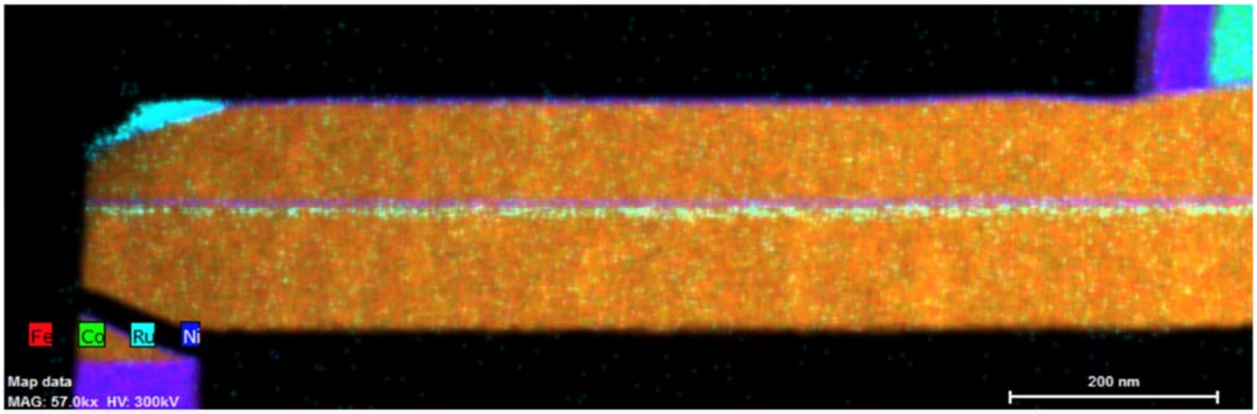

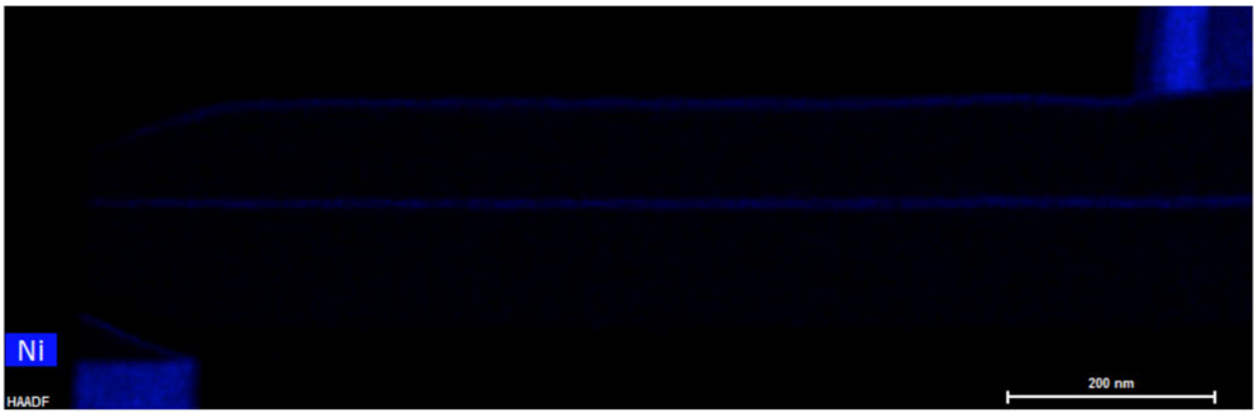

376. I further understand that Dr. Clark was able to conclude that the lower NiFe layer has an fcc crystal structure with its (111) planes parallel to the lower FeCo layer deposited above it. *See* Clark Report at Section F.2.a.3. Such a (111) oriented fcc crystal structure presents a (111) hexagonal surface on which the lower FeCo layer is grown. '988 patent at 14:55-57 ("The (111) textured fcc, (111) textured fcc derivative, or an (0002) textured hcp crystals are examples of the (111) textured hexagonal atomic template."). An illustration to show the hexagonal pattern present in the (111) plane of an fcc crystal is below.

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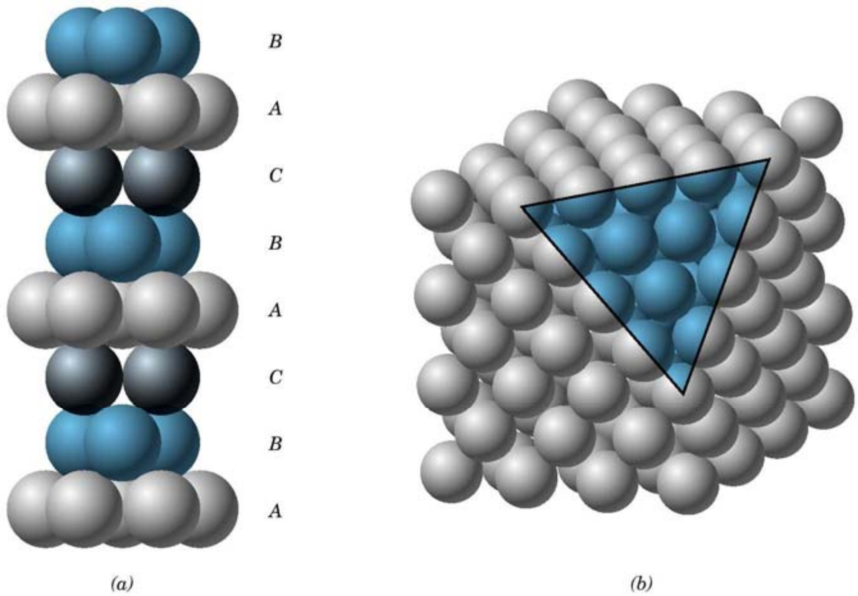

FIGURE 3.15 (*a*) Close-packed stacking sequence for face-centered cubic. (*b*) A corner has been removed to show the relation between the stacking of close-packed planes of atoms and the FCC crystal structure; the heavy triangle outlines a (111) plane. (Figure *b* from W. G. Moffatt, G. W. Pearsall, and J. Wulff, *The Structure and Properties of Materials,* Vol. I, *Structure,* p. 51. Copyright © 1964 by John Wiley & Sons, New York. Reprinted by permission of John Wiley & Sons, Inc.)

Callister at Fig. 3.15

377. I understand that Dr. Clark used FFTs to conclude that, for sample SBRD8K, the $(111)_{NiFe}$ plane is parallel to the $(110)_{FeCo}$ plane for the lower layers of each of NiFe and FeCo. *See* Clark Report at Section F.2.a.3. This relationship is characteristic of an epitaxial relationship between the fcc NiFe in the lower layer of NiFe and the bcc FeCo in the lower layer of FeCo. The existence of this epitaxial relationship indicates that the lower NiFe layer directs the growth of its overlying layer—that is, the lower FeCo layer. Further, I understand that this is the epitaxial orientation relationship characteristic of the Kurdjumov-Sachs six variant system was present in the lower FeCo and NiFe layers. *See id*. Accordingly, the lower NiFe layer in sample SBRD8Kdirects the growth of the lower FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system. As discussed above, sample SBRD8Kis representative of the [redacted] Products (*see* Section VII.1.a.) and, accordingly, I

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conclude that each of the [redacted] Products has a lower layer of NiFe that directs the growth of the lower FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system.

378. [redacted]

379. [redacted]

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[redacted]

380. [redacted]

381. [redacted]

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[redacted]

382. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers in the write pole of the [redacted] Products meet this limitation.

383. Therefore, the [redacted] products include at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer, which is the lower NiFe layer in the write pole. Thus, it is my opinion that element (d) of claim 1 of the '988 patent is literally met by the [redacted] Products.

12. Opinion No. 26: The [redacted] Products Infringe Claim 3 of the '988 Patent

a) Claim 3, "[t]he magnetic material structure recited in claim 1, wherein a surface of said substrate is amorphous or polycrystalline," is met by the [redacted] Products

384. Claim 3 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein a surface of said substrate is amorphous or polycrystalline."

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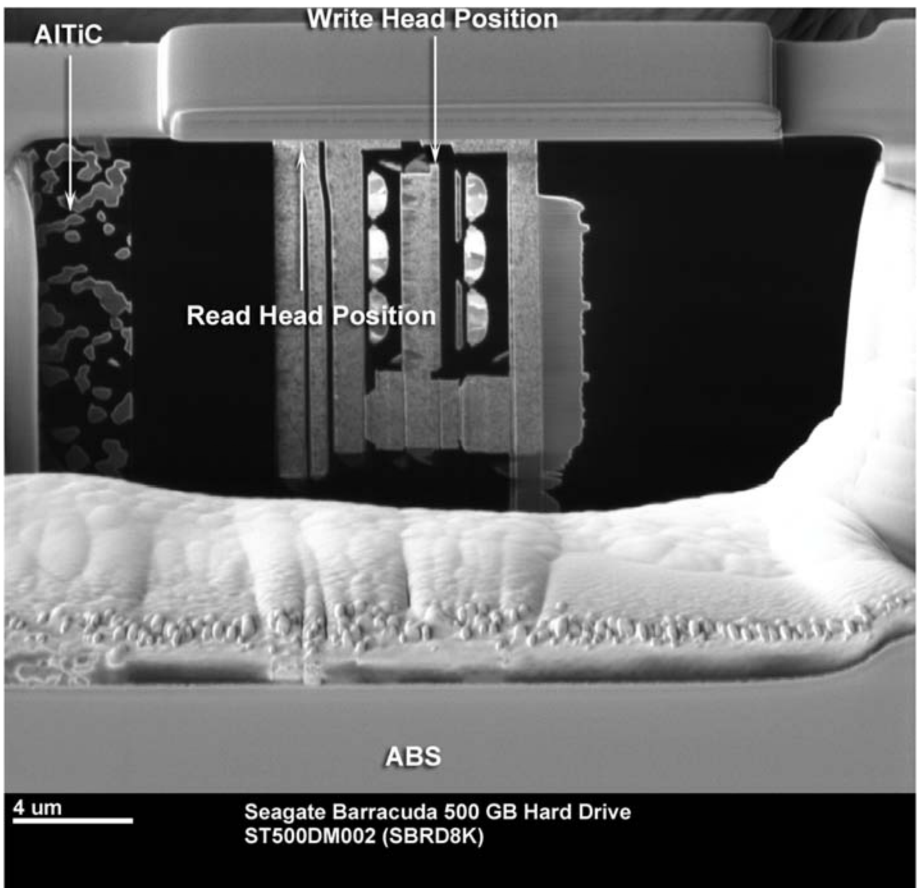
385. Claim 3 is literally met by the [redacted] Products. The [redacted] Products all include an AlTiC wafer that serves as the substrate, *see* Section VII.1.b., and has a polycrystalline surface. The polycrystalline nature of the entirety of the AlTiC substrate, including its surface, is observable in a representative [redacted] Product, specifically sample SBRD8K, via imaging in a FEI 200 TEM FIB gallium focused ion beam ("FIB") system during lift out of a cross-section sample. In the image below, the AlTiC wafer substrate is visible on the left side of the image and the material layers comprising the head, including the write pole, deposited on top of the AlTiC wafer substrate are visible to the right.



386. [redacted]

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387. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers in the write pole of the [redacted] Products meet this limitation.

388. Based this evidence, it is my opinion that claim 3 of the '988 patent is literally infringed by the [redacted] Products.

13. Opinion No. 27: The [redacted] roducts Infringe Claim 6 of the '988 Patent

a) Claim 6, "[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is formed from a fcc-d or hcp crystalline material," is met by the [redacted] Products

389. Claim 6 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is formed from a fcc-d or hcp crystalline material."

390. Claim 6 is literally met by the [redacted] Products. As discussed above, Dr. Clark analyzed the lower layer of NiFe in a representative [redacted] Product, specifically sample SBRD8K, through high resolution TEM imaging of a cross section and FFT analyses confirmed that the lower layer of NiFe had a fcc crystal structure, which is an fcc-d crystal structure under the Court's construction. *See* Clark Report at Section F.2.a.2. and F.2.a.3.

391. [redacted]

392. [redacted]

393. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers in the write pole of the [redacted] Products meet this limitation.

394. Based on this evidence, it is my opinion that claim 6 of the ‘988 patent is literally infringed by the [redacted] Products.

14. Opinion No. 28: The [redacted] Products Infringe Claim 7 of the ‘988 Patent

a) Claim 7, "[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is magnetic," is met by the [redacted] Products

395. Claim 7 of the ‘988 patent provides ""[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is magnetic."

396. [redacted]

397. [redacted]

398. [redacted]

399. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers in the write pole of the [redacted] Products meet this limitation.

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400. Based on this evidence, it is my opinion that claim 7 of the '988 patent is literally infringed by the [redacted] Products.

15. Opinion No. 29: The [redacted] Products Infringe Claim 9 of the '988 Patent

a) Claim 9, "[t]he magnetic material structure according to claim 1, further comprising: a second layer providing a (111) textured hexagonal atomic template, wherein said second layer is magnetic," is met by the [redacted] Products

401. Claim 9 of the '988 patent provides "[t]he magnetic material structure according to claim 1, further comprising: a second layer providing a (111) textured hexagonal atomic template, wherein said second layer is magnetic."

402. Specifically, the write pole of the [redacted] Products contains two layers of NiFe. The lower layer of NiFe is the first (111) textured hexagonal atomic template and was discussed in Section VII.1.f. above. The upper layer of NiFe in the write pole of the [redacted] Products serves as a second layer that provides an atomic template because it provides an atomic pattern upon which the middle layer of FeCo is grown and directs this growth of the middle layer of FeCo. Moreover, as discussed further below, I understand that the upper layer of NiFe is predominately (111) hexagonal by virtue of having a fcc crystal structure and a predominantly (111) texture. The upper layer of NiFe is also disposed between the substrate (the AlTiC wafer material discussed in Section VII.1.a. above) and the middle layer of FeCo.

403. [redacted]

[redacted]

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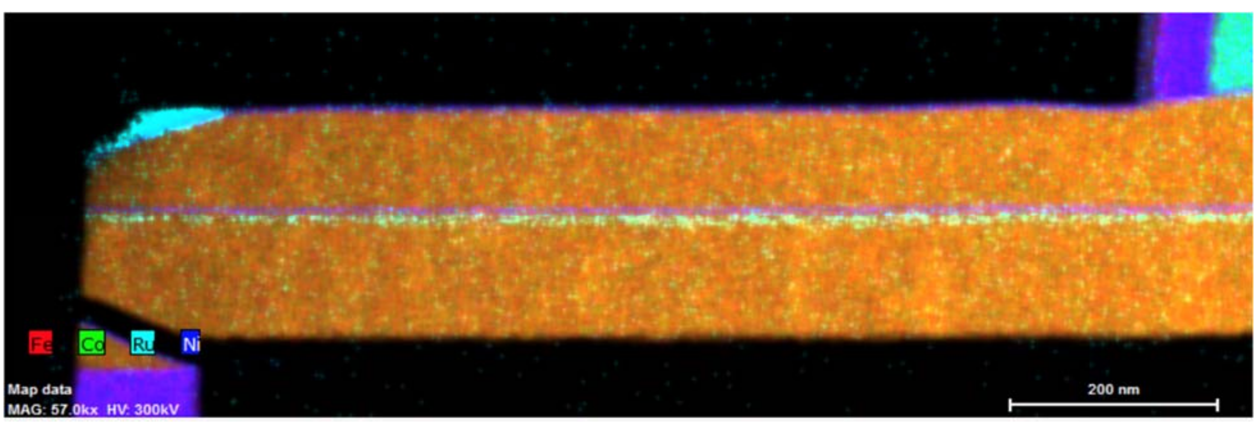
[redacted]

404. [redacted]

405. [redacted]

406. As discussed above, I understand that the presence of the two NiFe layers in the write pole of the [redacted] Products has been confirmed by EDS analysis performed on representative sample SBRD8K. *See* Clark Report at Section F.2.a.1. The presence of both the lower and upper NiFe layers can be observed in the images below.



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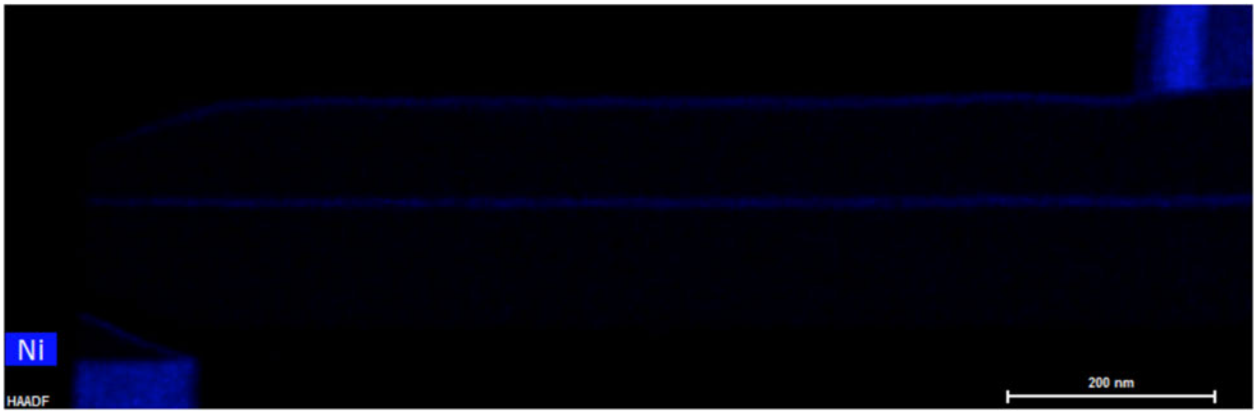

407. I further understand that Dr. Clark concluded that the upper NiFe layer has an fcc crystal structure with its (111) planes parallel to the middle FeCo layer deposited above it. *See* Clark Report at Section F.2.a.3. Such a (111) fcc crystal structure presents a (111) hexagonal surface on which the middle FeCo layer is grown. *See* Callister at Fig. 3.15; '988 patent at 14:55-57 ("The (111) textured fcc, (111) textured fcc derivative, or an (0002) textured hcp crystals are examples of the (111) textured hexagonal atomic template."). I understand that FFTs performed on TEM images from a cross-section of sample SBRD8K showed that the $(111)_{NiFe}$ plane is parallel to the $(110)_{FeCo}$ plane for the upper layer of NiFe and middle layer of FeCo. *See* Clark Report at Section F.2.a.3. This relationship is characteristic of an epitaxial relationship between the fcc NiFe in the upper layer of NiFe and the bcc FeCo in the middle layer of FeCo. The existence of this epitaxial relationship indicates that the upper NiFe layer directs the growth of its overlying layer—that is, the middle FeCo layer. Further, I understand that this FFT analysis indicated that a $\langle 110\rangle_{NiFe}$ direction is parallel to a $\langle 111\rangle_{FeCo}$ direction, *i.e.*, the epitaxial orientation relationship characteristic of the Kurdjumov-Sachs six variant system was present in the middle FeCo layer. *See id*. Accordingly, the upper NiFe layer in sample SBRD8K directs the growth of the middle FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system. As discussed above, sample SBRD8K is

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representative of the [redacted] Products (*see* Section VII.1.a.) and, accordingly, I conclude that each of the [redacted] Products has an upper layer of NiFe that directs the growth of the middle FeCo layer to having a (110) bcc texture and being oriented as a member of the Kurdjumov-Sachs six variant system.

408. [redacted]

409. [redacted]

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410. [redacted]

411. [redacted]

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412. Therefore, the [redacted] products include at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer, which is the upper NiFe layer in the write pole. Thus, it is my opinion that claim 9 of the '988 patent is literally infringed by the [redacted] Products.

16. Opinion No. 30: The [redacted] Products Infringe Claim 17 of the '988 Patent

a) Claim 17, "[t]he magnetic material structure recited in claim 1, wherein said bcc-d layer forming a uniaxial symmetry broken structure is composed of Fe or FeCo or an alloy of Fe or FeCo," is met by the [redacted] Products

413. Claim 17 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein said bcc-d layer forming a uniaxial symmetry broken structure is composed of Fe or FeCo or an alloy of Fe or FeCo."

414. [redacted]

415. [redacted]

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416. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers in the write pole of the [redacted] Products meet this limitation.

417. Based on reverse engineering of a representative [redacted] Product and Seagate's internal documentation and witness testimony, it is my opinion that claim 17 of the '988 patent is literally infringed by the [redacted] Products.

17. Opinion No. 31: The [redacted] Products Infringe Claim 19 of the '988 Patent

a) Claim 19, "'[t]he magnetic material structure recited in claim 1, wherein the layer material forming said (111) textured hexagonal atomic template is composed of Ag, Al, Au, Cu, fcc-Co, fcc-CoCr, Ir, Ni, NiFe, Pt, Rh, Pd, hcp-Co, Gd, Re, Ru, Tb, Ti, or alloys of one of these materials combined with at least one element," is met by the [redacted] Products

418. Claim 19 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein the layer material forming said (111) textured hexagonal atomic template is composed of Ag, Al, Au, Cu, fcc-Co, fcc-CoCr, Ir, Ni, NiFe, Pt, Rh, Pd, hcp-Co, Gd, Re, Ru, Tb, Ti, or alloys of one of these materials combined with at least one element."

419. [redacted]

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420. [redacted]

421. While my analysis herein concentrates on the lower NiFe layer and the lower FeCo layer, it is my opinion that all NiFe layers and overlying FeCo layers in the write pole of the [redacted] Products meet this limitation.

422. Based on reverse engineering of a representative [redacted] Product and Seagate's internal documentation and witness testimony, it is my opinion that claim 19 of the '988 patent is literally infringed by the [redacted] Products.

18. Opinion No. 32: The [redacted] Products Infringe Claim 27 of the '988 Patent

423. It is my opinion that the [redacted] X Products infringe claim 27 of the '988 patent. It is my opinion that every element of claim 27 is literally met by the [redacted] Products. I explain the foundation for my opinion on an element-by-element basis below. Alternatively, it is my opinion that the [redacted] Products infringe claim 27 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents. Accordingly, claim 27 is infringed by the [redacted] Products where "uniaxial" is met pursuant to the doctrine of equivalents and all other limitations are literally present.

424. I understand that the Court construed certain terms in claim 27 of the '988 patent. Specifically, I understand that the Court construed six terms from the claims of the '988 patent as reflected in the table below.

Term	Construction
"atomic template"	An atomic pattern upon which material is grown and which is used to direct the growth of an overlying layer

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Term	Construction
"[Layer] providing a (111) textured hexagonal atomic template"	Layer that is predominately (111) hexagonal and that provides an atomic template
"Uniaxial"	Having an anisotropy energy density function with only a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis
"Symmetry broken structure"	A structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system
"Uniaxial symmetry broken structure"	A structure that is uniaxial as a result of the structure being symmetry broken
"Variant/orientational variant" "Variants/orientational variants"	One of a set of possible crystal orientations Two or more of a set of possible crystal orientations
"bcc-d"	Either a body centered cubic or a body centered cubic derivative crystal structure
"fcc-d"	Either a face centered cubic or a face centered cubic derivative crystal structure

See Claim Construction Order, dated October 18, 2017, at 7-8. I have applied the Court's constructions for all construed terms in my infringement analysis. I have applied the plain and ordinary meaning according to a person having ordinary skill in the art to all non-construed terms.

a) To the extent the preamble to claim 27, "[a] magnetic device having incorporated therein a magnetic material structure comprising" is limiting, it is met by the [redacted] Products

425. The preamble of claim 27 of the '988 patent states "[a] magnetic device having incorporated therein a magnetic material structure comprising."

426. I understand that the preamble to a patent claim is generally not limiting. I further understand that Seagate has not sought construction of the preamble to claim 27 of the '988 patent and has not asserted that it is limiting. Nevertheless, the [redacted] Products are magnetic devices having incorporated therein a magnetic material structure.

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427. [redacted]

428. Thus, it is my opinion that, to the extent the preamble of claim 27 is limiting, it is met by the [redacted] Products.

b) Element (a) of Claim 27, "a substrate," is met by the [redacted] Products

429. Element (a) of claim 27 of the '988 patent provides "a substrate." This is the same language as the element (a) of claim 1 of the '988 patent.

430. Element (a) is literally met by the [redacted] Products. Specifically, the [redacted] Products include a substrate, for all of the reasons listed in Section VII.1.b. above. Thus, it is my opinion that element (a) of claim 27 is met by the [redacted] Products.

c) Element (b) of Claim 27, "at least one bcc-d layer which is magnetic," is met by the [redacted] Products

431. Element (b) of claim 27 provides "at least one bcc-d layer which is magnetic."

432. Element (b) is literally met by the [redacted] Products. Specifically, the [redacted] products include at least one bcc-d layer which is magnetic, for all of the reasons listed in VII.1.c. above. Thus, it is my opinion that element (b) of claim 27 is met by the [redacted] Products.

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d) Element (c) of Claim 27, "forming a uniaxial symmetry broken structure," is met by the [redacted] Products

433. Element (c) of claim 27 provides "forming a uniaxial symmetry broken structure."

434. Element (c) is literally met by the [redacted] Products. Specifically, the [redacted] X products include at least one bcc-d layer which is magnetic and forms a uniaxial symmetry broken structure, for all of the reasons listed in Section VII.1.d. above. Thus, it is my opinion that element (c) of claim 27 is met by the [redacted] Products.

e) Alternatively, the "uniaxial" limitation is met by the [redacted] Products pursuant to the doctrine of equivalents

435. Alternatively, it is my opinion that the [redacted] Products infringe claim 27 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents and, as I have explained, all of the other limitations of claim 27 of the '988 patent are literally present in the [redacted] Products. Based on all of the information discussed in Section VII.1.e., it is my opinion that, to the extent the "uniaxial" limitation is not literally satisfied by the [redacted] Products, this limitation is met pursuant to the doctrine of equivalents. Accordingly, claim 27 of the '988 patent is infringed by the [redacted] Products under the doctrine of equivalents.

f) Element (d) of Claim 27, "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer," is met by the [redacted] Products

436. Element (d) of claim 27 provides "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer."

437. Element (d) is literally met by the [redacted] Products. Specifically, the [redacted] products include at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer, for all of the reasons listed in

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Section VII.1.f. above. Thus, it is my opinion that element (d) of claim 27 is met by the [redacted] Products.

19. Opinion No. 33: The [redacted] Products Infringe Claim 28 of the '988 Patent

a) Claim 28, "[t]he magnetic device recited in claim 27, wherein the device is a magnetic data storage system," is met by the [redacted] Products

438. Claim 28 of the '988 patent provides "[t]he magnetic device recited in claim 27, wherein the device is a magnetic data storage system."

439. [redacted]

20. Opinion No. 34: The [redacted] Products Infringe Claim 29 of the '988 Patent

a) Claim 29, "[t]he magnetic device recited in claim 27, wherein the device is a data storage magnetic recording transducer," is met by the [redacted] Products

440. Claim 29 of the '988 patent provides "[t]he magnetic device recited in claim 27, wherein the device is a data storage magnetic recording transducer."

441. [redacted]

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[redacted].

21. Opinion No. 35: The [redacted] Products Infringe Claim 1 of the '988 Patent

442. It is my opinion that the [redacted] Products infringe claim 1 of the '988 patent. It is my opinion that every element of claim 1 is literally met by each of the [redacted] Products. I explain the foundation for my opinion on an element-by-element basis below. Alternatively, it is my opinion that the [redacted] Products infringe claim 1 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents. Accordingly, claim 1 is infringed by the [redacted] Products where "uniaxial" is met pursuant to the doctrine of equivalents and all other limitations are literally present.

443. I understand that the Court construed certain terms in claim 1 of the '988 patent. Specifically, I understand that the Court construed six terms from the claims of the '988 patent as reflected in the table below.

Term	Construction
"atomic template"	An atomic pattern upon which material is grown and which is used to direct the growth of an overlying layer
"[Layer] providing a (111) textured hexagonal atomic template"	Layer that is predominately (111) hexagonal and that provides an atomic template
"Uniaxial"	Having an anisotropy energy density function with only a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis
"Symmetry broken structure"	A structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system

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Term	Construction
"Uniaxial symmetry broken structure"	A structure that is uniaxial as a result of the structure being symmetry broken
"Variant/orientational variant" "Variants/orientational variants"	One of a set of possible crystal orientations Two or more of a set of possible crystal orientations
"bcc-d"	Either a body centered cubic or a body centered cubic derivative crystal structure
"fcc-d"	Either a face centered cubic or a face centered cubic derivative crystal structure

See Claim Construction Order, at 7-8. I have applied the Court's constructions for all construed terms in my infringement analysis. I have applied the plain and ordinary meaning according to a person having ordinary skill in the art to all non-construed terms.

a) To the extent the preamble to claim 1, "[a] magnetic material structure comprising" is limiting, it is met by the [redacted] Products

444. The preamble to claim 1 recites "[a] magnetic material structure comprising."

445. I understand that the preamble to a patent claim is generally not limiting. I further understand that Seagate has not sought construction of the preamble to claim 1 of the '988 patent and has not asserted that it is limiting, nor has the Court construed the preamble of claim 1 of the '988 patent to be limiting. Nevertheless, each of the [redacted] Products include a magnetic material structure.

446. [redacted]

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[redacted]

447. [redacted]

448. [redacted]

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[redacted]

449. [redacted]

450. [redacted]

451. Thus, it is my opinion that, to the extent the preamble to claim 1 is limiting, it is met by the [redacted] Products.

b) Element (a) of Claim 1, "a substrate," is met by the [redacted] Products

452. Element (a) of claim 1 of the '988 patent provides "a substrate."

453. [redacted]

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[redacted]

454. [redacted]

455. [redacted]

456. [redacted]

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457. [redacted], it is my opinion that element (a) of claim 1 of the '988 patent is met by the [redacted] Products.

c) Element (b) of Claim 1, "at least one bcc-d layer which is magnetic," is met by the [redacted] Products

458. Element (b) of claim 1 of the '988 patent provides "at least one bcc-d layer which is magnetic."

459. [redacted]

460. [redacted]

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[redacted]

461. [redacted]

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[redacted]

462. [redacted]

463. [redacted]

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[redacted]

464. [redacted]

465. [redacted]

466. [redacted]

467. Therefore, for at least the reasons described above, the [redacted] Products comprise at least one bcc-d layer which is magnetic. Thus, it is my opinion that element (b) of claim 1 of the '988 patent is met by the [redacted] Products.

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d) Element (c) of Claim 1, "forming a uniaxial symmetry broken structure," is met by the [redacted] Products

468. Element (c) of claim 1 of the '988 patent provides "forming a uniaxial symmetry broken structure."

469. [redacted]

470. [redacted]

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[redacted]

471. [redacted]

472. [redacted]

473. [redacted]

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[redacted]

474. [redacted]

475. [redacted]

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[redacted]

476. [redacted]

477. [redacted]

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[redacted]

478. [redacted]

479. [redacted] Products is uniaxial as a result of the being symmetry broken and, accordingly, it is my opinion that the [redacted] Products include material that forms a uniaxial symmetry broken structure.

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Therefore, it is my opinion that element (c) of claim 1 of the ‘988 patent is literally met by the [redacted] Products.

e) Alternatively, the "uniaxial" limitation is met by the [redacted] Products pursuant to the doctrine of equivalents

480. Alternatively, it is my opinion that the [redacted] Products infringe claim 1 of the ‘988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents and, as I have explained above, all of the other limitations of claim 1 of the ‘988 patent are literally present in the [redacted] Products.

481. [redacted]

482. [redacted]

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[redacted]

483. [redacted]

484. [redacted]

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[redacted]

485. [redacted]

486. [redacted]

487. Based on all of the information discussed above and in Section VIII.1.d., it is my opinion that, to the extent the "uniaxial" limitation is not literally satisfied by the [redacted] Products, this limitation is met pursuant to the doctrine of equivalents. Accordingly, claim 1 of the '988 patent is infringed by the [redacted] Products under the doctrine of equivalents.

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f) Element (d) of Claim 1, "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer," is met by the [redacted] Products

488. Element (d) of claim 1 of the '988 patent provides "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer."

489. [redacted]

490. [redacted]

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491. [redacted]

492. [redacted]

493. [redacted]

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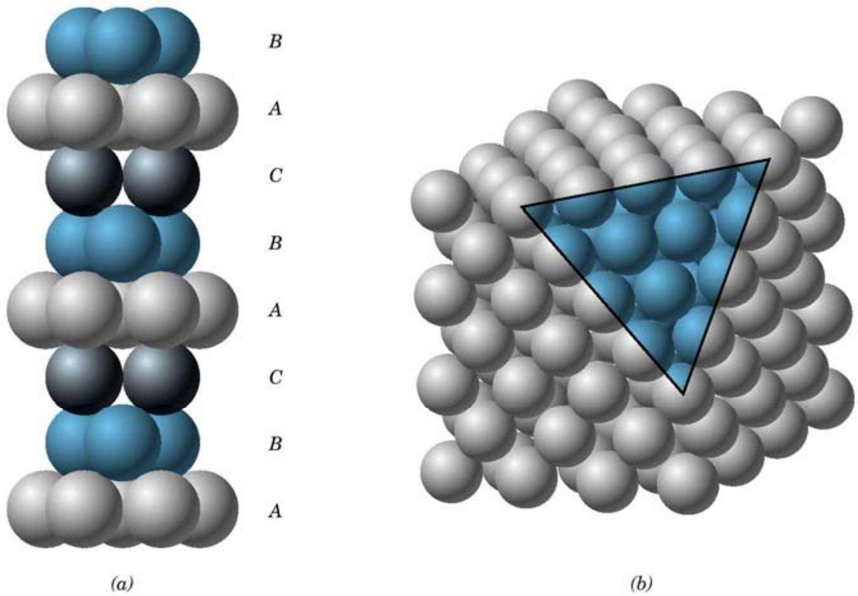

FIGURE 3.15 (*a*) Close-packed stacking sequence for face-centered cubic. (*b*) A corner has been removed to show the relation between the stacking of close-packed planes of atoms and the FCC crystal structure; the heavy triangle outlines a (111) plane. (Figure *b* from W. G. Moffatt, G. W. Pearsall, and J. Wulff, *The Structure and Properties of Materials,* Vol. I, *Structure,* p. 51. Copyright © 1964 by John Wiley & Sons, New York. Reprinted by permission of John Wiley & Sons, Inc.)

Callister at Fig. 3.15

494. [redacted]

495. [redacted]

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[redacted]

496. [redacted]

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[redacted]

497. [redacted].

498. Therefore, the [redacted] products include at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer, which is the [redacted] in the write pole. Thus, it is my opinion that element (d) of claim 1 of the ‘988 patent is literally met by the [redacted] Products.

22. Opinion No. 36: The [redacted] Products Infringe Claim 3 of the ‘988 Patent

a) Claim 3, "[t]he magnetic material structure recited in claim 1, wherein a surface of said substrate is amorphous or polycrystalline," is met by the [redacted] Products

499. Claim 3 of the ‘988 patent provides "“[t]he magnetic material structure recited in claim 1, wherein a surface of said substrate is amorphous or polycrystalline."

500. [redacted]

501. [redacted]

502. [redacted]

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503. Based on this evidence, it is my opinion that claim 3 of the '988 patent is literally infringed by the [redacted] Products.

23. Opinion No. 37: The [redacted] Products Infringe Claim 7 of the '988 Patent

a) Claim 7, "[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is magnetic," is met by the [redacted] Products

504. Claim 7 of the '988 patent provides ""[t]he magnetic material structure recited in claim 1, wherein the layer providing said hexagonal atomic template is magnetic."

505. [redacted]

506. [redacted]

507. [redacted]

508. [redacted]

509. Based on this evidence, it is my opinion that claim 7 of the '988 patent is literally infringed by the [redacted] Products.

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24. Opinion No. 38: The [redacted] Products Infringe Claim 17 of the '988 Patent

a) Claim 17, "[t]he magnetic material structure recited in claim 1, wherein said bcc-d layer forming a uniaxial symmetry broken structure is composed of Fe or FeCo or an alloy of Fe or FeCo," is met by the [redacted] Products

510. Claim 17 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein said bcc-d layer forming a uniaxial symmetry broken structure is composed of Fe or FeCo or an alloy of Fe or FeCo."

511. [redacted]

512. [redacted]

513. [redacted]

514. Based on this evidence, it is my opinion that claim 17 of the '988 patent is literally infringed by the [redacted] Products.

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25. Opinion No. 39: The [redacted] Products Infringe Claim 19 of the '988 Patent

a) Claim 19, "'[t]he magnetic material structure recited in claim 1, wherein the layer material forming said (111) textured hexagonal atomic template is composed of Ag, Al, Au, Cu, fcc-Co, fcc-CoCr, Ir, Ni, NiFe, Pt, Rh, Pd, hcp-Co, Gd, Re, Ru, Tb, Ti, or alloys of one of these materials combined with at least one element," is met by the [redacted] Products

515. Claim 19 of the '988 patent provides "[t]he magnetic material structure recited in claim 1, wherein the layer material forming said (111) textured hexagonal atomic template is composed of Ag, Al, Au, Cu, fcc-Co, fcc-CoCr, Ir, Ni, NiFe, Pt, Rh, Pd, hcp-Co, Gd, Re, Ru, Tb, Ti, or alloys of one of these materials combined with at least one element."

516. [redacted]

517. [redacted]

518. [redacted]

519. Based on this evidence, it is my opinion that claim 19 of the '988 patent is literally infringed by the [redacted] Products.

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26. Opinion No. 40: The [redacted] Products Infringe Claim 27 of the '988 Patent

520. It is my opinion that the [redacted] Products infringe claim 27 of the '988 patent. It is my opinion that every element of claim 27 is literally met by the [redacted] Products. I explain the foundation for my opinion on an element-by-element basis below. Alternatively, it is my opinion that the [redacted] Products infringe claim 27 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents. Accordingly, claim 27 is infringed by the [redacted] Products where "uniaxial" is met pursuant to the doctrine of equivalents and all other limitations are literally present.

521. I understand that the Court construed certain terms in claim 27 of the '988 patent. Specifically, I understand that the Court construed six terms from the claims of the '988 patent as reflected in the table below.

Term	Construction
"atomic template"	An atomic pattern upon which material is grown and which is used to direct the growth of an overlying layer
"[Layer] providing a (111) textured hexagonal atomic template"	Layer that is predominately (111) hexagonal and that provides an atomic template
"Uniaxial"	Having an anisotropy energy density function with only a single maximum and a single minimum as the magnetization angle is rotated by 180 degrees from a physical axis
"Symmetry broken structure"	A structure consisting of unequal volumes or unequal amounts of the bcc-d variants of a six variant system
"Uniaxial symmetry broken structure"	A structure that is uniaxial as a result of the structure being symmetry broken
"Variant/orientational variant" "Variants/orientational variants"	One of a set of possible crystal orientations Two or more of a set of possible crystal orientations
"bcc-d"	Either a body centered cubic or a body centered cubic derivative crystal structure
"fcc-d"	Either a face centered cubic or a face centered cubic derivative crystal structure

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See Claim Construction Order, dated October 18, 2017, at 7-8. I have applied the Court's constructions for all construed terms in my infringement analysis. I have applied the plain and ordinary meaning according to a person having ordinary skill in the art to all non-construed terms.

a) To the extent the preamble to claim 27, "[a] magnetic device having incorporated therein a magnetic material structure comprising" is limiting, it is met by the [redacted] Products

522. The preamble of claim 27 of the '988 patent states "[a] magnetic device having incorporated therein a magnetic material structure comprising."

523. I understand that the preamble to a patent claim is generally not limiting. I further understand that Seagate has not sought construction of the preamble to claim 27 of the '988 patent and has not asserted that it is limiting. Nevertheless, the [redacted] Products are magnetic devices having incorporated therein a magnetic material structure.

524. [redacted]

525. Thus, it is my opinion that, to the extent the preamble of claim 27 is limiting, it is met by the [redacted] Products.

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b) Element (a) of Claim 27, "a substrate," is met by the [redacted] Products

526. Element (a) of claim 27 of the '988 patent provides "a substrate." This is the same language as the element (a) of claim 1 of the '988 patent.

527. Element (a) is literally met by the [redacted] Products. Specifically, the [redacted] Products include a substrate, for all of the reasons listed in Section VIII.1.b. above. Thus, it is my opinion that element (a) of claim 27 is met by the [redacted].

c) Element (b) of Claim 27, "at least one bcc-d layer which is magnetic," is met by the [redacted] Products

528. Element (b) of claim 27 provides "at least one bcc-d layer which is magnetic."

529. Element (b) is literally met by the [redacted] Products. Specifically, the [redacted] products include at least one bcc-d layer which is magnetic, for all of the reasons listed in Section VIII.1.c. above. Thus, it is my opinion that element (b) of claim 27 is met by the [redacted] Products.

d) Element (c) of Claim 27, "forming a uniaxial symmetry broken structure," is met by the [redacted] Products

530. Element (c) of claim 27 provides "forming a uniaxial symmetry broken structure."

531. Element (c) is literally met by the [redacted] Products. Specifically, the [redacted] products include at least one bcc-d layer which is magnetic and forms a uniaxial symmetry broken structure, for all of the reasons listed in Section VIII.1.d. above. Thus, it is my opinion that element (c) of claim 27 is met by the [redacted] Products.

e) Alternatively, the "uniaxial" limitation is met by the [redacted] Products pursuant to the doctrine of equivalents

532. Alternatively, it is my opinion that the [redacted] Products infringe claim 27 of the '988 patent under the doctrine of equivalents because the "uniaxial" limitation is met under the doctrine of equivalents and, as I have explained, all of the other limitations of claim 27 of the '988 patent are literally present in the [redacted] Products. Based on all of the information discussed in

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Section VIII.1.e., it is my opinion that, to the extent the "uniaxial" limitation is not literally satisfied by the [redacted] Products, this limitation is met pursuant to the doctrine of equivalents. Accordingly, claim 27 of the '988 patent is infringed by the [redacted] Products under the doctrine of equivalents.

f) Element (d) of Claim 27, "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer," is met by the [redacted] Products

533. Element (d) of claim 27 provides "at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer."

534. Element (d) is literally met by the [redacted] Products. Specifically, the [redacted] products include at least one layer providing a (111) textured hexagonal atomic template disposed between said substrate and said bcc-d layer, for all of the reasons listed in Section VIII.1.f. above. Thus, it is my opinion that element (d) of claim 27 is met by the [redacted] Products.

27. Opinion No. 41: The [redacted] Products Infringe Claim 28 of the '988 Patent

a) Claim 28, "[t]he magnetic device recited in claim 27, wherein the device is a magnetic data storage system," is met by the [redacted] Products

535. Claim 28 of the '988 patent provides "[t]he magnetic device recited in claim 27, wherein the device is a magnetic data storage system."

536. [redacted]

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[redacted]

28. Opinion No. 42: The [redacted] Products Infringe Claim 29 of the '988 Patent

a) Claim 29, "[t]he magnetic device recited in claim 27, wherein the device is a data storage magnetic recording transducer," is met by the [redacted] Products

537. Claim 29 of the '988 patent provides "[t]he magnetic device recited in claim 27, wherein the device is a data storage magnetic recording transducer."

538. [redacted]

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CONTAINS CONFIDENTIAL ATTORNEY EYES ONLY
INFORMATION SUBJECT TO PROTECTIVE ORDER

Dated: May 2, 2018

Dr. Kevin Coffey

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CERTIFICATE OF SERVICE

I hereby certify that a true and correct copy of the within PLAINTIFF LAMBETH MAGNETIC STRUCTURES, LLC'S INITIAL EXPERT REPORT OF DR. KEVIN COFFEY is being served by e-mail upon all counsel of record on May 2, 2018.

RADULESCU LLP

/s/ Mindy Tsoi
Mindy Tsoi
Paralegal